HALL OF SCIENCE LECTURES

FIRST SERIES

HALL OF SCIENCE THURSDAY LECTURES.

FIRST SERIES.

PHYSIOLOGY OF HOME.	By	Annie Besant.
CHEMISTRY OF HOME.	„	Hypatia Bradlaugh.
WORKS OF SHAKSPERE.	„	Edward B. Aveling, D.Sc., F.L.S., etc.
ANTHROPOLOGY . . .	„	Chas. Bradlaugh.

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DIGESTION.

As it will be impossible for me in the small compass of four lectures to deal with the structure and functions of every organ of the body, I propose to select those an elementary knowledge of which will be most useful in home life. Much discomfort, much diminished vitality, much actual disease, are caused by ignorance of the simplest facts about our own bodies. How we digest, how we renew wasted material, how we breathe—these are matters closely concerning every one of us, and yet a majority of people are densely ignorant about them, and a vast mass of unnecessary suffering is the direct result of this ignorance. The object of these four lectures will be to throw a little light on the functions of digestion, circulation and respiration.

The most indifferent glance at the world of which we are a part reveals to us two great classes of phænomena; we see one kind of matter inert, passive, receptive, wrought upon by influences surrounding it but not actively moulding in return: clay, rock, metal, earth, all these are examples ready to our hands, and we label them non-living matter. The man lying on the cliff distinguishes between himself and the chalk on which he lies. He says, "I live; that lives not." The distinction may be accepted as a rough one, although it would be hard enough to draw the exact line which separates the living from the non-living, but for convenience sake we separate off the palpably living, and we call the science which deals with them Biology, the science of living things (βιος, life; λογος, a discourse).

Our work falls under this title. But the man on the cliff sees life around him other than his own; there is life in the trees, in the grass, in the flowers. Of living things there are again too great classes, and though the student knows that these again melt the one into the other, yet in the higher

forms of each there is such great divergence that we label them off separately once more, and call them severally Animal and Vegetable, and the sciences which deal with them Zoology (ζοον, animal; λογος), and Botany (βοτανη, a plant). Our work, again, falls under Zoology. We narrow it down yet further by putting on one side all animals save the highest, Man. And in studying man we find two great classes of facts; facts of Anatomy (ανα, up; τεμνο, I cut), facts of structure, which have to do with the form, material, and position of the organs of the body; and facts of Physiology (φυσις, nature: λογος), facts of function, which have to do with the work discharged by the organs. Both these last classes of facts will come under our notice, for though I shall deal mainly with functions, it will be necessary to touch briefly on the organs with which the functions are connected.

If you take a rope and use it constantly the material gradually wears away by friction until the rope is no longer serviceable; you throw it away and get a new one. If you work your muscles constantly the material of your muscles gradually wears away; you do not, however, require to throw them away and procure new ones. Why? The material of the rope is worn away bit by bit, and is not renewed; the material of the muscles is worn away bit by bit and is renewed. The wearing away of the muscle is as real as the wearing away of the cord; a man weighed before and after many hours of hard muscular exertion actually weighs less at the end than he did at the beginning. Even if he be idle the wearing away goes on, although less rapidly than when he is actively exerting himself. The place of this lost material must be filled up, else the muscle will wear out like the rope. The place of the wasted material is filled up in the living; and the discomfort caused by the blood exhaustion, consequent on repairing the waste, is known as the sensations of hunger and thirst, and the material is ultimately renewed by means of the food which appeases the want.

There are four chief ingredients in organised bodies; other substances also enter into them, but they are mainly made up of these four. Of these, three are gases, and one is a solid. The three gases are hydrogen, oxygen, and nitrogen; the solid is carbon. These four substances are

now before you, three are invisible, one is visible. But the three invisible ones are easily distinguished from each other by their properties. Without going fully into these—as the Chemistry of Home will be dealt with by my successor—I can show you that each apparently empty bottle contains a different substance. I apply a light to the first; it burns; it is hydrogen. I plunge a light into the second; the light is extinguished; it is nitrogen. I blow out a light leaving a red spark, and place it in the third; the spark bursts into a flame; it is oxygen. We have then, here, four different substances, from which we are to obtain muscle and nerve, blood and sinew, by which we are to replace the wasted materials in our bodies. The materials are scarcely promising. A starving man would hardly thank us for our three bottles and our lump of charcoal. But these four substances, elements as they are called, useless for food at present in their separate condition, have the useful property of combining very readily. Three chief combinations, or compounds, must be considered; water, carbonic acid, and ammonia. For convenience sake we use only the first letter of each element, instead of the full name. We have:

H	O	N	C
Hydrogen	Oxygen	Nitrogen	Carbon

These form:

H_2O	CO_2	H_3N
Water	Carbonic Acid Gas	Ammonia

And this is the first step towards our food-stuffs. The water is at once utilisable, but the other two are not yet food for us. But they are food for plants. The plants take into themselves the CO_2, and expelling the oxygen retain the carbon; they take the nitrogen from the ammonia and from ammoniacal bodies, and within themselves they so recombine them as to form food-stuffs suitable for animals. You will notice that the first compounds are each made up of two elements; the next set, manufactured by the plants, are mostly made up either of three or of four. They consist either of carbon, oxygen, and hydrogen, or of carbon, oxygen, hydrogen, and nitrogen. The two great divisions of food-stuffs depend on the presence or on the absence of nitrogen.

Let us take the non-nitrogenous, or as they are some-

times called the non-azotised, first. They are the food-stuffs containing only carbon, oxygen, and hydrogen. These are: (1) All the starchy matters; if you look at thin slices, sections, of potatoe, rice, sago, corn, and many other vegetable productions, under the microscope, you will see grains of starch in them; that starch has been manufactured by the plant and contains nothing but carbon, hydrogen, and oxygen in certain definite proportions. Gum, and other amyloids (from *amylum*, starch) are also found in plants. (2) All the sugary matters: the sugar of every-day life is obtained from the sugar-cane, the maple and the beet-root; the sweetness of ordinary fruit is due to the presence of another kind of sugar. Yet other kinds are formed by animals, and are present in milk, in muscle, in liver. (3) Fats and oils: some of these are formed in plants—such as palm-oil; others in animals. Now the whole of these three classes of food-stuffs have one main use when taken into our bodies: they produce heat. I must again so far trespass into chemistry as to tell you that heat is caused by the union of oxygen with some other substance. When oxygen enters into combination with other bodies heat is always given out. The substances that we have been considering part with oxygen very readily; they give it up as they are decomposed inside the body, and thus animal heat is maintained. Hence the necessity of starchy, sugary, and oily food-stuffs; the colder the country the more need for fatty articles of food. The Esquimaux finds the blubber of the whale delicious; the Arab would turn from it in disgust. Why? because the bitter cold of the North chills the body, and the body, in order to keep up the temperature necessary to life, needs a large supply of fatty matter, which readily yields up its oxygen for new combinations, that is which gives the agent needful for the production of heat. On the other hand the warmth of Arabia renders a comparatively small amount of fatty matter necessary for the maintenance of animal heat.

There are certain other food-stuffs, consisting of carbon, oxygen, and hydrogen, which are mainly stimulating. Such are the acids produced in fruits, the alcohols, and ethers. These substances act rapidly on the body, but their effect is not permanent. Brandy may appear to warm more immediately than a good meal, in which fat plays a part, but

an hour afterwards the man who has taken the brandy will be colder than before, while the man who has eaten will be thoroughly warm. Alcohol—generally termed spirits—is invaluable where a stimulant is necessary, say in the case of a person insensible from exposure to cold; it is not good as an ordinary article of diet.

I have said that the chief use of the starches, sugars, and fats is as heat-producers; the chief use of the second great class of food-stuffs, the nitrogenous or azotised, is as tissue-formers, that is, as builders up of the various tissues of the body. It may be well to note, in passing, that while nitrogenous food-stuffs are primarily tissue-formers, they do help, in small measure, to produce heat, and that while non-nitrogenous food-stuffs are primarily heat-producers, they also, to a small extent, aid in the formation of tissue. Nature refuses to be marked off by our sharp lines of division, and in her order work of one kind glideth ever into work of another.

In this great second class of food-stuffs, nitrogen—as the name of the class implies—is always present in combination with the carbon, hydrogen, and oxygen. The chief tissue-forming substances are albuminoids, like albumin, the white of eggs, and gelatinoids, like gelatin, the soft matter in bone. The albuminoids are some vegetable, some animal. Albumin is present in vegetables generally; legumin is found in such vegetables as peas, beans, pulse, etc.; gluten in cereals of all sorts. Hence the great value of wheat and of beans of all kinds as articles of food. Animal albuminoids are found in meat, blood, milk, and eggs.

Some nitrogenous food-stuffs, like some non-nitrogenous, are stimulating. Among these we find Thein, the essential characteristic of tea; Caffein, that of coffee; Theobromin, that of cocoa. These, like alcohol, are stimulants, but the nitrogen present in them adds to their nutritive power.

If you take these various food-stuffs, sugar, starch, fat, albumin, and so on, and place beside them some muscle, some nerve, some brain, and some blood, you still have the problem before you: How is the food-stuff changed into the materials which make up the body? In their solid form these substances are useless. There are no openings whereby solid matter can pass into the blood and reach the tissues; all nourishing matter passes into the blood by a

process called osmosis. Osmosis means passage through a membrane. If you take a bladder and fill it with sugar and water, and then place it in a vessel of pure water for an hour, you will find at the end of the hour that the water in the vessel is sweet. Some of the sugary water has passed out of the bladder into the vessel, while some of the pure water has, in turn, passed into the bladder. This exchange of liquids through a membrane which has no holes in it is called osmosis. By osmosis all the nutritive part of our food passes into the absorbent vessels, and it is, therefore, absolutely necessary that it shall be dissolved, that it shall be in solution, otherwise it cannot be taken up and used in the reparation of tissue. The next lecture will deal with the organs of digestion; at present I want only to show you the changes that take place in the food.

Take, first, the sugars. These are soluble in water. Place a piece of sugar in cold water inside a bladder; place the bladder in water. The sugar will dissolve, and by osmosis will pass into the water outside. We can prove its presence there by adding to the water copper sulphate and caustic soda, and then heating: if sugar be present, a red-brown powder is precipitated. The sugar is, then, very easily prepared for osmosis; it dissolves in simple water.

But the starch presents a difficulty. I have here some starch that has been placed in a bladder with water, and surrounded by water for twenty-four hours. But the water outside is as pure as when placed there. The starch has not passed through; we test the water by pouring in a little iodine, a substanee which gives a purple re-action with starch; we find nothing. Starch, then, as starch, is useless in the body. But in this second bladder starch has been placed, mixed with saliva, with the fluid poured into the mouth while we are eating. We test the water outside, and we find it is not pure water; it gives the characteristic re-action for sugar. What, then, has happened? The saliva has turned the insoluble, and therefore useless, starch into soluble sugar, ready to be taken up and used in the body. Whenever you eat bread this change goes on in the mouth. Hence the importance of thoroughly chewing the food, and the importance of checking children when they eat too fast. If bread is "bolted," the starch in it remains starch; it is useless for nutrition. It is true that there is

another fluid (from the pancreas, or sweetbread) which takes up the work left undone by the saliva, but if the saliva has not done its share too much work is thrown on the other; hence discomfort, and indigestion.

The fats are not affected by the saliva, and they pass through the stomach unaltered. They become very finely divided, made into "an emulsion" as it is called, in the upper part of the small intestine, and so become capable of osmosis.

The albuminoids are insoluble in their native state, but are acted upon in the stomach by the gastric juice, and are turned into what are called peptones. Peptones are merely albuminoids, so far as their composition is concerned, but their properties have been changed. You know that if you boil an egg the white "sets"; but white of egg which has been standing in gastric juice will not "set"; it is not affected by heat. White of egg will not pass through a membrane, and therefore cannot be absorbed; but white of egg, after standing in gastric juice, can pass through, and can be absorbed. Albuminoids, then, are changed in the stomach itself into the soluble form of peptones, and become ready to be taken up.

The food-stuffs, thus rendered soluble, are absorbed by a large number of little vessels which project into the small intestine; these vessels run together into one large one; the large one opens into a vein, and in this way the nourishing part of the food passes into the blood. The blood carries it to all the tissues of the body, and each tissue takes up the kind of material that it requires to make good what it has lost, and so the tissues, constantly wasting, are as constantly built up again.

It will now be very plain to you that the quantity and the quality of food required will vary very much according to the age and the work of the person dealt with, and will vary also with the climate in which he lives. A man who works hard, and therefore uses up his tissues quickly, will require more food than an idle man. An ordinary man in good work requires daily about 44,500 grains of food, and of this 4,000 grains should be carbon and 300 nitrogen (Huxley). He may choose for himself the form in which he will take them. To live entirely on meat is not good, for 1,000 grains of meat contain (roughly) 100 of carbon and 30 of nitrogen,

so that it would be necessary to eat some 6 lbs. of meat to get carbon enough, although 1½ lbs. give sufficient nitrogen. On the other hand, if you live only on bread, you must eat twice as much carbon as you require in order to get enough nitrogen. In either case the system is overworked by more matter being put into it than is required. A mixed diet of animal and vegetable food is the diet recommended by Physiology. Animal food seems especially necessary for the reparation of nervous tissue, but further experiment is wanted before we can lay down exactly the kind of food needed for the reparation of each tissue of the body.

The food of children should be, above all things, nourishing and easily digestible. The corn-flours so largely sold for children's food are mostly deficient in gluten, while rich in starch, and are not, therefore, sufficiently tissue-forming. The same is true of ordinary white bread. Milk, wholemeal bread, beans of all sorts, oatmeal, and fruit, with comparatively little meat, form the most wholesome diet for children.

The mineral constituents of food have been omitted in this rough sketch; with the exception of salt, they are taken in as part of ordinary animal and vegetable food, and are found unaltered in the various tissues. The chief of these are: Sodium Sulphate and Sodium Phosphate in the blood and secretions; Potassium Chloride, Potassium Sulphate, and Potassium Phosphate in the muscles; Calcium Carbonate, Calcium Phosphate, and Magnesium Phosphate in the bones; Iron Oxide in the blood.

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ORGANS OF DIGESTION.

In speaking last week of facts of Zoology, we divided them into two classes:—Anatomy, which includes all facts of structure; Physiology, which includes all facts of function. Our work this week is chiefly anatomical; we are to deal with the Organs of Digestion.

Let us be sure, first, that we understand the words we are using. What is an *organ?* What is *digestion?*

An organ is any special portion of a body which is set apart for any special kind of work. In the lowest animals all parts of the body do all kinds of work equally well. The Amœba, for instance, grasps, eats, digests, breathes all over its body. There are no special portions set apart for special work: that is, there are no organs. A little higher up in the scale a mouth appears, and a bag that receives the food. Instead of taking in food all over, the food is taken in at the mouth. The mouth is the organ for food-reception, and so on. The higher the animal, the more complete is this division of labor, and the organs become more and more different, more and more perfect in the discharge of their particular work.

Digestion is, to borrow Dr. Aveling's definition, "the preparation of food for absorption." Absorption is the taking up of digested food, in order that it may be carried to the blood, and so reach the tissues; digestion is getting the food ready for absorption, so changing it that it may be fit to be taken up.

To sum up, "organs of digestion" are specialised parts of the body which prepare food for absorption.

All the changes undergone by the food during digestion take place in the alimentary canal. Aliment is merely another name for food, and the alimentary canal is the tube along which the food passes. This tube begins at the

mouth and ends at the anus, and is about 30 feet in length. You will remember that there are no openings in it save these two, excepting, of course, the openings into it of ducts, little tubes, from its own appendages. Imagine, then, a long tube, expanding at one end into the mouth, expanding again, some way down, into the stomach; twisting and turning very much as the small intestine; expanding for the third time to form a little side-bag, the cæcum; widening to make the large intestine which encircles the small, and the short comparatively straight rectum. This canal has three coats: one is of mucous membrane, and forms the lining of the canal, so that it comes into contact with the food; the middle one is of fibrous tissue, and serves to connect the important inner and outer coats; the outer coat is muscular. This last coat is composed, excepting in the stomach, of two layers of muscles. One layer is of fibres running round the tube; the other layer is of fibres which run lengthwise along the tube. Now muscle has one great quality, it contracts. If you take a piece of indiarubber and pull it, it yields to your pull and stretches; when you let go, it springs back. You say it is elastic; it lengthens easily and shortens again when released, or you may shorten it by pressure and it will lengthen when released. This is just what muscle does; it stretches readily and contracts readily. Hence the use of the two layers in the muscular coat. The circular layer contracts, and makes the tube narrower and longer; the longitudinal layer contracts, and makes it shorter and wider. We shall see presently how useful these contractions are. The alimentary canal has, further, various appendages connected with it, each appendage having its own definite function. Having thus briefly described it as a whole, let us now turn to details.

THE MOUTH AND ITS APPENDAGES.—The mouth is nearly oval in shape, and is the organ which receives the food, and in which digestion begins. The soft red lining is the mucous coat. The chief appendages are the tongue, the teeth, and the salivary glands. *The Tongue* may be dismissed in a sentence: it is a thick strip of muscle, the organ of taste, and serves to turn the food about in the mouth so as to submit it to the action of the teeth, and finally to roll it into a ball and pass it backwards to the top of the gullet.

The teeth are the organs of mastication; their work is to

crush and bruise the food, to break it up. The use of this is obvious. If a cook is going to make soup, she does not throw the bones in whole: she breaks them up into pieces, so that all parts of them may come into immediate contact with the water, and thereby more quickly and readily yield up their useful components. What the cook does to the bones, the teeth do to the food. By breaking it up, all parts of it come into contact with the saliva and more readily submit to its action. How necessary this is, you will remember from last week. The teeth, however, are not all alike; the first set, or milk-teeth—cut during infancy—are twenty in number. These teeth begin to develop in the seventh week of fœtal life; a little groove appears, running along the jaw, and in this groove grows up a ridge of soft (mucous) tissue; parts of this ridge die off, and so leave little projecting pieces, called papillæ; each of these represents a future tooth. I have not time to describe all the changes that go on; it must suffice to tell you that the sides of the groove bend over and close in the papillæ, so that when the child is born you see no groove and no papillæ, but only the smooth surface of the gum. The papillæ develop into teeth, hard matter being laid down in them, and they cut their way through. The permanent teeth have been forming at the same time, and move gradually round underneath the milk-set. The latter fall out from about the sixth year onwards, and the permanent teeth come through; they are supposed to be complete about the twenty-first year, when the "wisdom teeth" ought to be through. There are 32 permanent-teeth; 8 incisor, or cutting teeth, the "front teeth"; 4 canine, the long pointed teeth on either side, above and below; 20 "double teeth," for grinding. The canine teeth are for tearing, and are of no particular use to us, but they are interesting as showing our descent from animals who tore their food. A glance at a picture of a double tooth shows the structure of all; you see the fang, which is imbedded in a depression (called an alveolus) and holds the tooth firmly in its place; then comes the neck, the narrower part, and then the crown, visible above the gum. This crown is covered with enamel, the hardest tissue in the body, which protects the tooth from injury. If this gets worn away, or injured, the softer parts underneath rapidly decay. Hence the importance of keep-

ing the teeth thoroughly clean, and of not taking into the mouth substances which injure the enamel. Inside the tooth is a cavity filled with pulp and with a nerve running into it. Toothache constantly arises from the hard part of the tooth getting worn through, and this nerve becoming exposed. When this happens, the only thing to do is to have the nerve killed and the hole filled up—stopped, it is called: the remainder of the tooth may thus be saved.

The Salivary glands are six in number—three pairs, the parotid, submaxillary, and lingual. Each of these consists of masses of cells, or vesicles, and from these masses of vesicles go ducts which run together to form a larger duct, which opens into the mouth. A gland is an organ which secretes. To secrete (from *secreto*) is to separate one thing from another, to take out one kind of substance and leave the rest. The cells, or vesicles, of the gland do the work, and they take out of the blood substances which are needed for use in the body, or sometimes which need to be expelled from the body. The salivary glands secrete saliva, and they pour this substance into the mouth and there it works, as we saw last week, on the starchy constituents of food.

From the mouth the food passes over the windpipe, which is closed by a sort of trapdoor, into the PHARYNX, the part just behind the mouth. From the pharynx a tube, about nine inches long, goes to the stomach, and this tube is called the ŒSOPHAGUS. And now comes in the use of our two muscular layers. Food which leaves the pharynx does not tumble down into the stomach. It is seized by a ring of the circular fibres, which contract on it; when they let it go, the next ring seizes it, and so it is handed on step by step till it reaches the stomach. Some of you may have seen a conjurer drink water while standing on his head, and may have wondered how it got up, instead of down, to his stomach. It is the circular rings of the œsophagus that do all the work, and as the food is handed on to ring after ring, it makes no difference whether it goes upwards or downwards.

THE STOMACH. The œsophagus opens into the stomach, the expanded part of the alimentary canal, the opening being closed except when food is passing by a ring called a sphincter muscle. The stomach is like a bag, larger on the left side than on the right, and lies across the body just

below the liver. As it is part of the alimentary canal it has, of course, the regular three coats, but the muscular coat has three layers instead of two, and in addition to the longitudinal and circular it has also a layer of oblique fibres, and when all these are contracting and lengthening a kind of churning motion is given to the contents of the stomach, and the food is turned over and about, and thoroughly mixed. In the lining, or mucous coat, there are a number of little glands of different kinds, which secrete fluids and pour them into the stomach. The most important of these are the peptic glands, which secrete the gastric juice. When albuminous matter arrives in the stomach, this gastric juice is secreted and is poured out; the movements of the stomach mix the juice well up with the food, and the changes we spoke of, and which you saw last week, take place. As the gastric juice does its work the soluble portions of food—called chyme—are pumped out of the stomach into the small intestine. They pass through another sphincter muscle, the pylorus or door keeper, and until the stomach digestion is finished, this muscle will not allow any solid matter to pass. When the stomach has completed its work neither food nor chyme remains in it; it is left perfectly empty, and the secreting action of the glands stops entirely.

THE SMALL INTESTINE AND ITS APPENDAGES. The small intestine is about twenty feet long, and is divided into three districts, the duodenum, jejunum, and ileum. In the *duodenum*, active digestion continues. Into this part of the intestine are poured the secretions from the liver and pancreas, as well as fluids secreted by little glands in its own lining mucous membrane. The liver is the large organ which you see covering the stomach, and lying to the right side of the abdominal cavity. It secretes the bile, and as it secretes constantly while the bile is only used intermittently, the bile is stored up in the pear-shaped organ attached to the liver, called the gall-bladder. The exact work of the bile is still rather a matter of dispute. It appears to act as a stimulant to the intestine, it is to some extent an excrementitious product—that is, a waste fluid carrying off matters injurious to the body—and it is also certainly antiseptic—that is, prevents decomposition. The pancreas lies partly in the fold of the abdomen and secretes the fluid which, as we saw last

week, makes an emulsion of the fats and oils, and also finishes work left undone by the saliva in turning starch into sugar. The pancreatic fluid runs down a little duct, and joins the duct from the liver, the two opening together into the duodenum.

The *jejunum* is so called because it is generally found empty after death, the *ileum* because it is much twisted. All these three parts of the small intestine are thickly studded with villi, little projections like the finger of a glove, which stick out into the canal of the small intestine. Each villus has a little tube, or tubes, in it, called lacteals, and all these are plunged into the digested food—now called chyle—and suck it up as fast as they can. They absorb the nutritive matter, the fluid passing through their delicate walls, as you remember, by osmosis. As the villi continue to suck up the fluid, the contents of the intestine become more and more solid; they are slowly passed along by the muscular movements of the intestine until they arrive at the cæcum.

THE LARGE INTESTINE.—The large intestine commences at the *cæcum*, and is about five feet long. The cæcum itself is a mere blind bag, small in man, but large in many of the lower animals. So far as we know, it serves no useful purpose in man, but it is occasionally the cause of disease, by lodging hard particles which give rise to inflammation. When the digested food reaches the cæcum, it has yielded up most of its nutritive material, and the remaining matter is useless, and has to be expelled from the system. The large intestine, here called the *colon*, passes first upward (ascending colon), then turns to the left and crosses the body (transverse colon), turns downwards (descending colon), and then makes a remarkable S-like turn (sigmoid flexure). Throughout its length it is sacculated—drawn into little bags, or sacculi—and as the superfluous portion of the food, now called fæces, passes along it, being carried on as before by the muscular movements of the intestine, it gets lodged in the sacculi, and is so prevented from falling back between the contractions. This muscular movement—peristaltic action, as it is termed—may be very easily seen by pinching the intestine of an animal which has been lately killed: a slow wave of movement will run along it. The last six or eight inches of the intestine are named the *rectum*, and extend from the sigmoid flexure to the anus. The rectum

is not sacculated, increases in diameter as it descends, and ends in a sphincter muscle.

You may reasonably ask, what causes all these movements, whereby the food is propelled along the alimentary canal, from mouth to anus? We are not conscious of these muscular contractions, nor are they, mostly, under the control of the will. When a morsel of food has reached the top of the œsophagus it passes out of our power. We do not even feel it pass down the œsophagus unless it is very hot, very cold, or actively injurious. Unhappily our time is too brief to allow us to go fully into this interesting question. It must suffice to say that muscle left to itself does not contract. But distributed to all these muscles of the alimentary canal are a number of fine cords called nerves. When the nerve contracts it moves the muscle, and all the muscular movements are the result of nervous action.

But you may again ask: What causes the nervous action? It is a property of nerve to respond to a stimulus. When the nerve responds to an external stimulus, and responds without sensation—that is, the stimulus causes action, but we are unconscious of the action—such nerve-action is called reflex. Reflex action is action caused by external stimulus, and performed without sensation. The whole of the movements of the œsophagus, stomach and intestines are reflex. The stimulus is the food pressure. The food presses against the delicate nerve fibres; the nerve-fibres, responding to this stimulus, are set in motion; moving, they move the muscles to which they are distributed, and the muscles contract. The food is pushed on by the contraction, presses against fresh nerve-fibres, and so on. If the nerves are destroyed, the muscular contractions stop, showing that the muscles do not contract of themselves. Destroy the nerves, and the food may press for ever against the muscles without causing them to contract.

We must now return, in conclusion, to the small intestine, and see what becomes of the chyle. We have already seen that each villus contains a tube or tubes; these minute tubes run into glands (mesenteric glands) in the mesentery, the thin membrane that connects together the folds of the intestine, and here the chyle undergoes considerable changes. Corpuscles—small rounded bodies that we shall speak more of when we come to deal with the blood—make their

appearance, the constituents of fibrin are formed, and the chyle changes in color from white to a pale reddish-yellow. This modified chyle is collected in a triangular cavity or cistern (*receptaculum chyli*), which lies at the back of the body, against the backbone. From this cistern a duct (thoracic duct) runs up along the backbone as far as the root of the neck, being from eighteen to twenty inches in length; at the top it turns to the left and arches downwards, entering the blood system at the junction of the internal jugular and subclavian veins, and pouring its contents into the blood.

We have thus traced our food from its four primary elements until it reaches the blood, which is to carry it to repair the tissues, and have briefly sketched the organs which work upon it and change it. The next lecture will deal with the organs to which the food is now committed, and with the way in which the blood nourishes the body.

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CIRCULATION.

We defined an *organ* last week as "any special portion of a body which is set apart for any special kind of work." The first things we have to consider to-night are the Organs of Circulation, the special portions of the body concerned in the circulation of the blood.

The organs of circulation are of four kinds: the heart, the arteries, the capillaries, the veins.

The Heart.—The heart lies obliquely between the lungs in the upper half of the trunk, the apex pointing forward and rather to the left, the broad upper end being in the middle line of the body. The average adult human heart is about 5 inches long, 2½ inches thick, and 3½ inches broad in the widest part. It is conical in shape and hollow, and is divided within into four compartments, the right and left auricles, and the right and left ventricles. A septum (*septum*, a fence) runs from base to apex, completely dividing the right side from the left, so that there is no communication possible between the two sides in a healthy person. This septum has an auricle and a ventricle on either side of it, and each auricle communicates with the ventricle of its own side. The material of the heart is muscle, of which you will remember the chief characteristic is contractility. The muscular walls are not of the same thickness throughout; those of the auricles being considerably thinner than those of the ventricles, and the wall of the right ventricle being thinner than that of the left. You all know that exercise strengthens muscles; the arm of a blacksmith is larger and harder than that of a writer, and when we find that there is so great a difference between the walls of these cavities we may feel sure that the greater thickness is the result of greater work. The work of the heart is to propel the blood, and the propulsion of the blood outside the heart falls wholly on the ventricles; the muscular walls of the ventricles, being more used, generation after generation, have become permanently thicker than those of the auricles; similarly, while the right ventricle has only to propel the blood round

the lungs, the left has to drive it all round the body, hence the muscular wall of the left is thicker than that of the right. The openings (auriculo-ventricular orifices) between each auricle and the ventricle of its own side are oval in shape and surrounded by a fibrous ring. The openings are guarded by valves, folds of the lining membrane of the heart, which are in such a position that they can completely close the aperture. On the right side the valve is composed of three triangular segments (tricuspid valve, from *tres*, three, and *cuspis*, a point), while the similar valve on the left side has two (mitral valve, so-called from its supposed resemblance to a mitre). The description of one of these valves will serve for both. The segments of the tricuspid valve are attached by their bases to the fibrous ring, their points being free. From these free points and from the surface on the ventricle side, go thin cords of tendon, a fibrous inelastic tissue, and these cords (*chordæ tendinæ*) are attached to little muscular pillars (*musculi papillares*) three or four in number, projecting from the inner wall into the cavity of the ventricle. These cords are long enough to allow the segments of the valve to join each other and completely close the auriculo-ventricular opening; they are not long enough to allow the points of the valves to be pushed up into the auricles. We shall now be able to understand what happens when the heart "beats," that is contracts and expands; the "beat" is caused by the apex of the heart striking against the wall of the chest. Imagine the heart empty, or, if you are wise, get a bullock's heart and experiment; imagine some fluid pouring into the right auricle, till it is full; the auricle contracts and presses on the fluid; the fluid tries to escape, and the easiest way out of the auricle is through the opening into the ventricle; it pours through, the valve yielding readily and being flattened against the walls of the ventricle by the rush from above; the ventricle becomes full and begins to contract, forcing the fluid once more to escape. Meanwhile the segments of the valve have been pushed up as the ventricle fills until they nearly meet, and the fluid, pressed by the contraction of the ventricle, pushes against them and completely closes them; it continues to push against them, but the *chordæ tendinæ* prevent them from going upwards any further, and the fluid is compelled to escape into an open tube, called the pulmonary artery, leading out of the ventricle. A very sharp hearer might say: "As the ventricle contracts the

sides come nearer together, and therefore the valve would gradually rise into the auricle if pressed from below." Quite so, if the cords were attached directly to the wall of the ventricle, but you will remember that they are attached not to the wall, but to little pillars projecting from the wall, and as these also are of muscle they contract at the same time as the wall, and becoming shorter keep the cords tense. There are not many adaptations more beautiful and more remarkable than this, so to speak, compensating contraction.

ARTERIES.—An artery is a vessel, a tube, which carries blood away from the heart. This tube has three coats, a lining of serous membrane, a fibrous, better termed a muscular coat, and an outer of a very simple tissue, called connective. The middle coat is thick and strong in the large arteries, hence these are exceedingly elastic. Two great arteries rise from the heart, the pulmonary (*pulmo*, a lung) from the right ventricle, the aorta from the left. The pulmonary divides and sends a branch to each lung; these branches divide again and again within the lung. These are the only arteries in the body that contain impure blood. The aorta sends branches all over the body, to the head, trunk, and limbs, and these contain pure blood, keeping every tissue in working order.

CAPILLARIES.—The arteries, after dividing in this fashion, open at length into the capillaries (*capillus*, a hair), minute vessels varying in diameter from $^1/_{1500}$ to $^1/_{3000}$ of an inch. These capillaries form a fine, close network, the meshes of which vary very much in size. The network is closest wherever nourishment is most required and most rapidly used, for the actual work of nutrition goes on in the capillaries. In some parts the space between the capillaries is actually less than the diameter of a capillary, so that the nourishing blood is brought into the very closest contact with every part of the tissues. When I add that the wall of a capillary is a very delicate homogenous membrane, you will see how easily the tissues can, by osmosis, take out of the blood whatever they require.

VEINS.—A vein is a vessel which carries blood towards the heart. Like the artery, it has three coats, but the middle one is very thin, and in consequence of this the veins are but slightly elastic. Another great distinction between arteries and veins is the valves found in most of the latter. These valves are folds of the lining, shaped much like watch-pockets, with the opening directed towards the heart.

If, therefore, the blood be flowing towards the heart, the valves are pressed against the walls of the vein, and offer no impediment to the circulation. But if the blood begin to flow back, the pockets at once fill, become distended, and bar the passage. The use of this is obvious. Blood has to return to the heart from the lower part of the body against the force of gravity, and these valves prevent it from falling backwards. The veins begin where the capillaries end, just as the capillaries begin where the arteries end. The veins nearest the capillaries are very minute; they join to make larger ones, join again and again, until at last all the blood from the lower part of the body is gathered in the inferior *vena cava*, and all the blood from the upper part, except from the lungs, into the superior *vena cava*, and these two pour their contents into the right auricle. All the blood from the lungs is poured into the left auricle by four pulmonary veins.

Course of Circulation.—We can now trace the course of the blood. We divide the circulation of the blood into two systems—the greater, or systemic, and the lesser, or pulmonary circulation. We will take the greater first. Blood that has been aërated in the capillaries of the lungs is poured into the left auricle through the pulmonary veins. It passes through the auriculo-ventricular opening into the left ventricle. As the heart contracts, it is forced to find a way of escape. The mitral valve closes the opening into the auricle, but the aorta is open, and it rushes into that. Through artery after artery it travels, its containing vessel ever growing smaller and smaller, until it reaches a capillary network. Through this it travels slowly, very slowly, yielding up its nutritive material, and at length passes into a vein. Travelling now towards the heart, it passes on and on, its containing vessel ever growing larger and larger, until it reaches either the inferior or the superior *vena cava*. It flows into the right auricle, and through the auriculo-ventricular opening into the right ventricle, and has concluded the systemic course. There is, however, no rest for it. The contracting ventricle drives it out, and as the opening into the auricle is closed by the tricuspid valve, it is driven through the only other opening into the pulmonary artery. It goes either to the right or left lung, through the capillaries, through the veins, back into the left auricle, whence we traced its course, thus completing the pulmonary circulation. All the blood that has been round the body

goes to the lungs; all the blood that has been round the lungs goes to the body. Why?

ARTERIAL AND VENOUS BLOOD.—The question finds its answer in the difference between the blood returned to the heart from the body, and that returned to it by the lungs. The words "arterial" and "venous" are not very accurate, but they are generally used; they are inaccurate, because the pulmonary artery contains venous blood, and the pulmonary vein arterial. The most striking difference between arterial and venous blood is that of color; the arterial is scarlet, the venous purple. The most important difference is the presence of much oxygen in the arterial, of much carbon dioxide (carbonic acid gas) in the venous. Oxygen is breathed in by the lungs, and this oxygen is carried by the blood to the tissues; it enters into combination with the carbon of the tissues, and carbon dioxide (carbonic acid gas) is formed; this is not wanted, is even harmful, in the body, and it is carried away by the blood. In the arteries there is scarlet oxygenated blood; in the capillaries the oxygen is yielded to the tissues, the carbon dioxide is taken from the tissues; in the veins there is purple deoxidised blood, charged with CO_2, requiring purification in the lungs.

CAUSE OF THE CIRCULATION.—This constant movement of the blood now needs to be explained. The primary cause of the movement is the alternate contraction and expansion of the heart. The heart is a muscle, it is therefore very contractile. The stimulus to the nerves, causing them to act on the muscle, is the blood. When the blood fills the heart, it stimulates nervous action, the nerves act on the muscular fibres and they contract. The blood expelled, the stimulus is absent, the muscle relaxes and the heart expands. And so, alternately, we have contraction and expansion. Remembering that the blood will always move in the direction of least resistance, we at once understand why, on being pressed out of the heart, it rushes into the pulmonary artery and the aorta. The movement of the blood, however, does not depend only on the contraction of the heart; the elasticity of the arteries aids and regulates the flow. The moment the rush of the blood consequent on the contraction of the heart has ceased, the aorta in turn contracts on the blood; it would flow back to the heart, but the ever useful valves, this time (semilunar valves) round the aortic opening interpose, and the contracting artery

forces the blood onwards. This action of the arteries gives rise to the "pulse." The pulse is the expansion of the artery at a particular point, responding to the impulse sent from the heart. The blood is thus pushed on through the arteries, each "beat" of the heart driving fresh blood into the aorta, so pressing on the blood already there. In the capillaries the blood is pushed on from behind, and is also aided by several agencies classed under the head of "capillary action," which time does not permit me to deal with. In the veins it is propelled by the pressure from behind, and also sucked on, as it were, by the emptying of the heart in front. Any attempt to flow backwards is, as we have seen, checked by the valves. It is practically useful to remember the several directions in which the blood flows in the arteries and veins; suppose a limb be badly cut and a surgeon be not at hand. If the cut have severed an artery the blood will be bright scarlet, and will flow in regular jets, like water pumped out; if this be the case, remembering that arterial blood flows away from the heart, twist a bandage very tightly *above* the injury, so as to cut off the supply coming from the heart. If a vein be severed the blood will be dark and flow steadily, without any jerking motion; in this case, remembering that venous blood flows towards the heart, twist the bandage tightly *below* the wound, so as to cut off the supply coming from the capillaries.

BLOOD.—It is time to answer the question; "What is blood?" Gray very well defines it as "a fluid holding a number of minute cells or corpuscles in suspension." The corpuscles (*corpusculum*, a little body) are of solid matter, forming about $^1/_7$ of the blood; there are also other solid materials in the blood, albumin, fat, salt, and sugar, making up another $^3/_{28}$, so that $^1/_4$ of the blood is solid and $^3/_4$ water. This calculation is very rough, for the composition of blood is not a constant. If blood be left standing, the liquid and solid parts will separate out, and we have a clot surrounded by fluid. In the clot, entangled among structureless strings, called fibrin, we find the corpuscles, and these are of two kinds, white and red. The white are cells, constantly change their shape, and closely resemble the white corpuscles of chyle; the red are semi-solid bi-concave (hollowed on each side) discs, and are two or three hundred times more numerous than the white. These corpuscles are the gas-carriers, and the difference of color

between arterial and venous blood is thought to be due merely to the difference of the refraction of light severally from rounder or more flattened corpuscles.

The function of blood is to nourish and to equalise the temperature of the body. We have seen food transmuted into chyle, and the chyle poured into the blood system; when we further learn that the liquid part of the blood (*liquor sanguinis*) and the liquid part of the chyle (*liquor chyli*) are identical, and that little difference can be found between the white corpuscles of the blood and those of the chyle, we have not much difficulty in tracing our foodstuffs into the capillaries and, by osmosis, into the tissues.

Evolution of Heart.—In studying the wonderful mechanism of the heart, the marvellous adaptation of the organ to the function which it is its work to discharge, we are almost compelled to ask: "How did all this come into existence?" If the human heart were the only one known to us, the question would be hard to answer, but we are fortunately able to trace the evolution of the heart from a most imperfect beginning to its present condition. Without dwelling on the mere tube of insects, and passing over the very simple hearts of the invertebrate animals, let us hastily glance at the hearts of the great divisions of the vertebrate (back-boned) kingdom. The lowest class of the Vertebrata is that of the fish, Pisces. In the lowest again of these, the Amphioxus, the heart is a simple tube, a "pulsatile cardiac trunk" (Huxley), and "contractile dilatations" aid in propelling the blood. The typical fish's heart has two chambers, one auricle and one ventricle, and may be regarded as the tube, bent upon itself. In the highest fish, the heart acquires three chambers, two auricles, and one ventricle, thus graduating into the normal heart of the second vertebrate class, the Amphibia, of which the common frog is the best-known representative. Here the heart has two auricles, of which the right receives the venous blood from the body, and the left the arterial blood from the lungs. Unfortunately the frog has only one ventricle, and as both auricles open into it, and discharge their contents into the ventricle at the same time, the blood it contains is to a great extent mixed. Certain folds and valves tend to prevent complete mixing throughout, but the result is scarcely satisfactory. An advance is made in the next case, the Reptilia, and here we may take the snake as an example. The snake's heart has two auricles and one

ventricle, but there is an incomplete partition separating the ventricle into two halves, one containing venous and the other arterial blood, and when the heart contracts, this partition almost divides the ventricle into two chambers. In the highest Reptilia, the crocodile has a four-chambered heart, the septum becoming complete; this great advantage is, however, neutralised by the main arterial and venous trunks crossing just outside the heart and communicating by an opening, or foramen as it is called, and the blood mixing through this. In the birds (Aves) and the mammals (Mammalia) the heart has four separate chambers and the arterial never mixes with the venous blood.

We have thus a steady gradation from the tube of Amphioxus, through the two-chambered heart of the common fish; the three-chambered of the frog; the three-chambered, but with partially divided ventricle, of the snake; the four-chambered, but with communication outside, of the crocodile; up to the four-chambered, with uncommunicating vessels, of the bird and the mammal. Thus we see gradual evolution of a more perfect type, each improvement first hinted at, then introduced, then perfected.

In the development of the individual a similar evolution takes place. The heart is at one time a mere straight tube, the veins connected with one end, the arteries with the other. It soon becomes doubled on itself, and shortly afterwards a longitudinal septum grows out dividing it into two chambers. Later, two septa grow out transversely, dividing off the auricles from the ventricles. Still the separation of arterial and venous blood is not complete, for there is an opening between the auricles, the *foramen ovale*, and there is also a duct from the right ventricle to the aorta. The *foramen ovale* closes at birth, except in cases of disease (*morbus ceruleus*), and the duct is completely closed by the tenth week after birth. Thus the evolution of the race is to some extent repeated in the evolution of the individual, and the development of the infant traces for us the development of humanity.

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RESPIRATION.

RESPIRATION is the purification of the gases of the blood. We have seen that the corpuscles of the blood are gas-carriers; that they carry to the lungs from the tissues the carbonic acid gas which has been formed in work and which needs to be expelled, and also carry from the lungs to the tissues the oxygen which is required for use in the body. We have now to investigate the organs of respiration and the method in which the function is discharged.

ORGANS OF RESPIRATION. These are: the nose; the mouth; the pharynx; the larynx; the trachea; the bronchi; the bronchial tubes; the air-sacs and air-cells; the skin. The bronchial tubes, air-sacs and air-cells may be included generally under the *lungs*; the nose, mouth, pharynx, larynx, trachea and bronchi, may be regarded merely as the *air-passages* leading to the lungs. Some of you may be surprised at my mentioning the skin as an organ of respiration, but when I remind you that the body of a medium-sized full-grown man daily gets rid of 400 grains of carbonic acid gas through the skin, you will see that the skin comes fairly within the definition of an organ of respiration, that is, of a special part of the body which purifies the gases of the blood.

We will consider 1st, the air-passages; 2nd, the lungs; 3rd, the skin.

The *air-passages* opening on the exterior are two, the nose and the mouth. Both these passages open internally into the pharynx. If the mouth be closed, respired air passes into the two anterior nares, or nostrils, up the nasal fossæ (*fossa*, a ditch or trench), and through the two posterior nares, little openings into the pharynx. The air has thus arrived at the top of the throat, just behind the mouth. If, instead of breathing through the nose, you breathe through the mouth, the air passes straight to the pharynx; so that in

either case it arrives at the back of the mouth. The presence of these posterior nares, or internal nostrils, explains how, if you are bathing, water may run up your nose into your throat, or how, in smoking, you may take smoke into the mouth and breathe it out at the nose. Into the pharynx opens the *larynx*, a kind of box, triangular above, rounded below, which is situated at the top of the trachea, or windpipe. The larynx is formed of nine cartilages, one of which, the thyroid, is especially prominent in men, and is known as the *pomum Adami*, or Adam's apple. It is closed above by a little lid of cartilage, the epiglottis, and contains the vocal cords, the delicate strings of our voice-machine. When food passes from the mouth to the œsophagus it goes over this lid, the larynx being drawn beneath the tongue; the lid is then shut down, the hinge, so to speak, of the lid being just behind the tongue. When food "goes the wrong way," it is because this process has been imperfectly performed, and the morsel has slipped into, or wedged itself against the larynx, so obstructing the air-passage. Hence the danger of laughing or speaking when food is passing into the gullet. "Don't speak with your mouth full," is a maxim of physiology as well as of politeness. Any action which raises the epiglottis opens the air-passage, and a passing morsel may enter and cause suffocation. We have not time to dwell on the action of the vocal cords, we must content ourselves with passing by them into the trachea, or windpipe.

The *trachea* is a tube of about 4½ inches in length, and is formed of membrane with cartilaginous rings running two-thirds of the way round. These rings are imperfect behind, where the trachea comes into contact with the œsophagus, along the front of which it lies. The trachea divides into the two *bronchi*, the right bronchus, about an inch long, going to the right lung, and the left, about two inches in length, going to the left. When the bronchus enters the lung it divides and subdivides, forming the *bronchial tubes*.

The lungs are partly made up of the numberless ramifications of these bronchial tubes, but before dealing with these it will be well to pause for a moment on the *thorax*, the cavity which contains the lungs. This cavity is a perfectly air-tight box, bounded by the backbone behind, the breast-bone in front, and the ribs on either side, the interstices of the ribs being filled with the powerful intercostal muscles.

The bottom of the box is formed by the diaphragm, a remarkable muscle, shaped something like a fan, attached in front to the lower end of the breastbone, at the sides to the ribs, at the back to the vertebral column, and arching over the abdomen. The diaphragm is pierced by the œsophagus and the great blood vessels, but adheres closely round them, permitting no air to enter. The thorax contains, besides the lungs, the heart which lies between them and all the great vessels and nerves connected with heart and lungs, as well as the greater portion of the œsophagus. The liver and stomach lie immediately below it, being separated from the thorax by the diaphragm. The position of the diaphragm varies according to circumstances. When the lungs are partially emptied the diaphragm is much arched, the concave side being toward the abdomen. When air is breathed in the diaphragm is partially flattened, enlarging the cavity of the thorax. After a full meal, the diaphragm is pushed upwards by the extension of the stomach, and the oppression in breathing felt after an excessive meal is due partly to the upward pressure of the diaphragm against the lungs.

Before quitting the question of the thorax, a few moments must be devoted to the cause of our regular breathing. You will have noticed that I have laid stress on the fact that the thorax is perfectly air-tight. If it were not so breathing would be impossible. When air is expired from the lungs it is driven out partly by the elasticity of the lungs themselves, the bronchial tubes contracting upon it and expelling it. The outward motion is also perhaps assisted by delicate cilia—hair-like processes from the lining of the tubes—which constantly sweep outwards the solid and liquid contents. The muscles of the chest also come largely into play in expelling the air, by lessening the cavity of the thorax. Their several movements are too complex to be described in a lecture like this. The diaphragm, lastly, does a share of the work; like all muscles it contracts, and when it contracts it becomes flatter and therefore descends, and as the ribs are rising while the diaphragm is descending, the thoracic cavity enlarges, and air rushes in to fill the space thus given. The whole of the muscular action is, as before, controlled by nerves, and is reflex, not voluntary. We can partly control it by our will, and we can voluntarily hasten or slacken the movements; but

in the normal healthy condition, respiration goes on without our notice. As the normal number of respirations in a minute is fifteen, it would clearly be excessively troublesome if the brain had to see that the work went on properly; the task falls conveniently to the nonsensating division of our nervous system.

One difference may be worthy noting, the difference between male and female breathing. In the male the diaphragm is very much used; in the female it plays a comparatively small part, while the muscles connected with the ribs are the chief agents. Notice the breathing of a man and a woman, and see how much more the bosom of the latter rises and falls; the upper ribs are coming largely into play, while in the man they do but little work. A moment's thought, and the remembrance of the way in which Nature adapts beings to their life-conditions, will suggest to you the "why" of this difference. Woman is the reproducer of the race; during many months of her life, before she gives birth to a child, violent movement of the diaphragm would result in injury, and the condition necessary for health in one part of life becomes a sexual characteristic, common to the whole.

Let us return now to the anatomy of the lung, the surroundings of which we have been considering. Each lung is covered by a double membrane, one fold of the membrane clothing the lung, the other fold lining the cavity of the thorax, in which the lungs and heart are enclosed. Between these two folds is a small quantity of fluid, which enables them to run smoothly over each other. Inflammation of the pleuræ, or of these coats of the lungs, is the painful and dangerous disease known as pleurisy. The lung is composed of a large number of lobules, or little lobes. Each lobule consists of a little branch of the bronchial tube—which subdivides, each subdivision ending in a minute expansion or *air-sac*—and the nerves, blood-vessels and lymphatics in close relation to it, all being held together by connective tissue. A number of these lobules make up a lobe, and of these lobes the right lung has three, the left two. Reverting for a moment to the air-sacs mentioned above, it is necessary to add that in the walls of the air-sacs are little alveoli, depressions, very badly called *air-cells*. These range from $^1/_{70}$ to $^1/_{200}$ of an inch in diameter, and over the walls of each of these cells

spreads a net work of capillaries, into which pours the dark carbonic-acid-burdened blood from the subdivisions of the pulmonary artery, and out of which flows the scarlet oxygen-laden blood to the pulmonary veins. So close is the capillary net work that the space between the capillaries is only from $^1/_{500}$ to $^1/_{125}$ of an inch. By osmosis, once more, the carbonic acid gas passes out and the oxygen passes in. The oxygen is brought down to the air-cells as part of the air through all the passages that we have been considering. Air is a mixture chiefly of oxygen and nitrogen, the nitrogen serving merely to dilute its too vigorous companion; the oxygen in the air breathed into the lungs is seized upon by the corpuscles, and they give up in exchange the deleterious carbonic acid gas, which passes up the air-passages and out of the mouth or nose.

The exchange of oxygen for carbonic acid gas is not the only difference in inbreathed and outbreathed air. Expired air is of a higher temperature than inspired, and it is also charged with a considerable amount of water in the condition of steam. It is estimated that the lungs of an ordinary adult send out daily about 5,000 grains (9 ozs.) of steam, and 12,000 grains of carbonic acid gas, but it must be remembered that the amount of steam and of carbonic acid gas thus exhaled depends not only on the age, but also on the work of the individual.

Before speaking of the effect of this action on the air, we must complete our brief study of the organs of respiration by considering the *skin*. The skin is composed of two distinct layers, differing in nature, the scarf-skin, cuticle, or epidermis above, and the true skin or derma lying below. In the true skin, or sometimes just below it, are a number of small bodies called sweat-glands, and from these run ducts, which open by a tiny valve on the exterior of the body. By these is discharged the watery matter, known as perspiration, and if a limb be tied in an indiarubber bag it is found that the air within the bag becomes charged, not only with aqueous matter but also with carbonic acid gas. Since 400 grains of carbonic acid and 10,000 grains of water are thus discharged daily by the skin, the enormous importance of the healthy action of the skin at once becomes apparent. Let dust fall on the skin and mixing with the perspiration clog the openings of the valves, and the dis-

charge is at once checked; the matter that ought to be got rid of is kept in the body; the other excretory organs try to get rid of it, the lungs chiefly working at the carbonic acid gas and the kidneys at the water; over much labor is thereby thrown upon these organs, and they suffer. How is all this mischief to be prevented? The answer comes in one word: cleanliness. The body needs to be thoroughly washed, and where people work hard in dusty atmospheres the necessity is the more stringent. The public baths now found in London are veritable hygienic institutions, and men, women, and children who visit them will find doctors' visits less frequent.

VENTILATION.—We have seen that every person is continually breathing oxygen into the body, and is continually breathing out carbon dioxide, or carbonic acid gas. Hence it results that if a person be shut up in a room to which oxygen has no admittance, he will gradually use up the oxygen therein contained, and gradually replace it with carbon dioxide. As soon as the carbon dioxide amounts to 1 in 1,000 parts, the air of the room will begin to have an oppressive odor. The man will get drowsy and disinclined to exertion; a little later he will sink down half-sleeping, half-fainting; if he be left unrescued, he will die, and he will die not of any active poison administered to him, but from privation of the oxygen necessary for the maintenance of life. Carbon dioxide is sometimes called a narcotic poison, but it is not the presence of carbon dioxide that kills; it is the absence of free oxygen. When in crowded rooms people faint, they faint from want of oxygen; the venous blood carried to the lungs is not oxygenated there; it goes back to the left side of the heart still charged with carbon dioxide. In this condition it is supplied to the tissues. The brain receives this, instead of the fresh bright blood which it is in need of; giddiness, drowsiness, faintness, are the immediate consequences, and, if the mischief be allowed to continue, these result in death. A modified form of this injury is caused whenever a room is "close," although actual faintness may not ensue. People are so afraid of "draughts" that they prefer the "closeness," not knowing that the latter is really more dangerous than the former. But there is no need to suffer either from draughts or from closeness. Cut a slip of wood, about an

inch thick, to fit along the bottom sash of a window; shut the window down upon this. It will seem quite closed; but if you look at the middle of the window, where the bolt comes, you will see a slit as wide as your piece of wood. Fresh oxygen from outside will rise through this, and, spreading upwards, will cause no draught. If, in addition, you leave your window half an inch open at the top, you will feel no uncomfortable stream of cold air, but your room will be healthily ventilated, and your brain will be the clearer for it. One other agent we may call to our help in ventilating our rooms. Flowers are not only beautiful, they are also health-giving. They feed on the carbon dioxide, so long as light falls upon them, and, retaining the carbon, they excrete the oxygen. Although they breathe just as we do, taking up oxygen and breathing out carbon dioxide, yet, as long as they are in the light, they feed so much more than they breathe that their total effect upon the air is to diminish the carbon dioxide in it, and to increase the free oxygen. Flowers are, therefore, really useful in the room, and while they bring light and grace, color and sweetness into our homes, they also come as messengers of health, working for us as purifiers of the air.

Much unnecessary lung disease is caused by mere carelessness. Remembering the delicate machinery of capillary network and minute air-cell that I have traced for you, you will readily understand that rapid changes of temperature, or the introduction of foreign materials would very easily disorganise the mechanism. Yet people go suddenly out of a hot, close room into keen, cold air, unthinkingly subjecting these exquisite machines to the mischievously sudden alteration of temperature. A handkerchief placed over the mouth for a few moments after passing into the outer air from a hot room would prevent many a "bad cold on the chest."

Various trades are characterised by special lung diseases. If you pay a visit to a surgical museum, you may see lungs preserved there of miners, cotton-spinners, etc. The miner suffers from coal-dust breathed into the lungs in the air; the cotton-spinner from cotton-fluff carried thereinto in similar fashion; the Sheffield grinder from steel-dust. These dangers might be lessened in the last two cases by the continual swinging of large fans in the work-rooms, driving away the dust; they might be completely avoided by the wearing of respi-

rators by the workers, as all dust would be stopped in these, instead of going on into the lungs.

Again, as to clothing. The apex of each lung rises about an inch or an inch and a half above the line of this first rib. The lower part of the neck, therefore, needs to be protected even more than the chest itself. Yet mothers let babies and little children play about in the open air in winter in low-necked frocks, and then wonder that they suffer from cough, bronchitis, and inflammation of the lungs.

This brief course of lectures has now come to an end. I shall have wholly failed in my object, if it has only served to amuse some idle hours. I trust rather that our talks may have raised the desire to know more of a most interesting subject, and will lead many to study fully that which has been so superficially treated here.

PRICE ONE PENNY.

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AIR.—I.

THE Chemistry of Home is a very wide subject; even by eliminating Organic Chemistry and confining myself entirely to the Inorganic branch there is comparatively but a small instalment of the subject I can deal with. Men, women, and children, rich and poor, all are obliged to breathe air and use water; the white man breathes the same free air as his colored brethren; the teetotaller and the wine drinker both use the same kind of water. Therefore since air and water are universally required, I cannot do better than tell you something of what is known about these two substances. Of course we all know a little about them, but what we do not all understand is: the reason why sea air and country air are so much more invigorating than the air of towns—it is not wholly the absence of smoke, as I shall show you presently—what it is in the air that serves as food for plants, for plants require food just as much as we do; why some water is bright to look at and pleasant to taste, while other water is dull in appearance and absolutely tasteless. To-night, and during the next three Thursday evenings, I propose, with your permission, to explain the causes of these and similar phænomena. At this stage I ought to explain two or three terms which I shall often have occasion to use. First—by Chemistry is meant the study of elements, compounds and mixtures; by Inorganic Chemistry, that study limited to such elements, compounds and mixtures as are derived from the mineral kingdom. By an Element is meant a body which has not yet been further decomposed, that is to say, heat it as much as you like, subject it to any known processes, and whatever you may do to it you cannot break it up into any two or more bodies. This charcoal, this sulphur, this copper—these are elements. Aristotle taught that there were four elements only—Earth, Water, Air or Steam and Fire. To-day we are acquainted with sixty-four, and it is of these, or of compounds of these with each other, that our entire globe is composed. If we put two or more substances together and each retains its own characteristics, the resulting substance is called a mixture. To show what I mean by mixture, I will put some Copper and Flowers of Sulphur together. I mix them well, but you may recognise even in the body of the Hall the pieces of Copper or the yellow Flowers of Sulphur. I can pick out either of them with my fingers, and I find them in exactly the same condition as when I put them

together. Plum pudding is a mixture; even in a well-made pudding—and we English are famous for our plum puddings—you may easily distinguish raisins, citrons, currants, and other ingredients. To make clear the distinction between mixture and compound I will now heat this Copper and Sulphur over the spirit lamp. (Ex.) You may see the contents of this capsule have turned black; you cannot distinguish either the Copper or the Sulphur, in fact they are no longer here as such; they have combined to form a compound known as Copper sulphide, a substance not in the least resembling either of its constituents, but having entirely new properties. In a mixture, then, we have two or more substances put together, and each retaining its own characteristics: while in a compound we have two or more substances put together ceasing to be distinguishable, and thus forming an entirely new one. This marble, this sugar are compounds. Aristotle taught that air and water were elements, and although the word element was then used in a different sense to that employed to-day, nevertheless it was thought that air and water were simple bodies, until the investigations of Priestley and others showed air to be composed of two gases, one whereof is capable of supporting combustion and respiration. In 1774 Priestley—who was a celebrated chemist and metaphysician—discovered that this one was Oxygen; and in 1781, just 100 years ago, the repeated experiments of Cavendish—another remarkable man—proved that air contained two different gases in almost constant proportion. Then several chemists maintained that air was a compound, to-day we know that it is a mixture; and water also, instead of being an element, has been proved to be a compound. Air is a mixture of several gases, of which the chief are Nitrogen and Oxygen. That you may see this practically for yourselves I propose to show you a little experiment; indeed, so far as it is possible, I intend to prove every important illustration by simple experiments, and as chemical experiments have the reputation of generally coming to grief, I must ask you to be indulgent towards me should any of mine follow the usual course. I am now going to prove roughly to you that the chief gases in our atmosphere are Nitrogen and Oxygen and for that purpose I have here a glass-stoppered vessel, called a bell-jar containing air—the ordinary air of this room; a pneumatic trough partly filled with water; a watch glass, and a very small piece of Phosphorus. I put the Phosphorus into the watch glass and float them upon the water in the trough—now I will ignite the Phosphorus and cover it with the bell-jar, so that the rim of the jar comes just below the surface of the water.

When Phosphorus or, indeed, anything burns it is said to undergo combustion, and combustion, generally speaking, means union with Oxygen. The Phosphorus burning in this jar full of air is simply uniting with the Oxygen contained therein—and it will burn as long as there is any Oxygen in the jar—forming these dense white fumes, known technically by the name of Phosphorus pent-oxide. I can give you no common name for Phosphorus pent-oxide, but

pent-oxide means that there are five parts of oxygen in this compound. Pent is from the Greek word πεντε, meaning five. Now, as Phosphorus pent-oxide is extremely soluble you will soon see these fumes subside, absorbed by the water. The water will rise in the jar until it occupies the space formerly occupied by the Oxygen, this you will see is one-fifth of the entire space. The gas occupying the remaining four-fifths of the jar is Nitrogen. You will say that it looks to you very much like air, that it looks very much as it did before I ignited the Phosphorus except that the water has risen in the jar. Well, Nitrogen is very much like air in appearance; they are both colorless, odorless, and transparent, air is a trifle heavier than Nitrogen, but I cannot very well show you that with the gas contained in this jar. There is, however, one way of settling the question as to whether it is air or Nitrogen that we have here. I light a taper—you see it burns well enough in the air—now Nitrogen gas does not support combustion, therefore, if this be Nitrogen in the jar, when I put the lighted taper into it the light will be extinguished. (Ex.)

The air we have just experimented upon was only ordinary air, therefore, from what we have just seen, we may draw a very important conclusion, namely, that, roughly speaking, atmospheric air is composed of one-fifth Oxygen and four-fifths Nitrogen. A few minutes ago I said that air was a mixture of several gases, and yet the proportions I now give to Nitrogen and Oxygen leave no margin for any other gases. Quite true, but from experiments made upon air from which all other gases have been withdrawn—sometimes called pure air, because a similar mechanical mixture of Nitrogen and Oxygen answers nearly all the purposes of ordinary air—Oxygen and Nitrogen have invariably been found in almost exactly the same proportions of four-fifths Nitrogen and one-fifth Oxygen. The other gases present in the atmosphere will be dealt with by and bye. Nitrogen is, then, as you see, colorless, odorless, and a non-supporter of combustion; it is also very difficult to make it enter directly into combination. From its incapability to support life it has been called by some chemists *azote*, from α=without and ζωη=life, but as there are other gases which resemble it in that respect the more distinctive name for it is Nitrogen, from *nitrum* = nitre, and γενναο = I produce, because it may be largely obtained from nitre or saltpetre. All its properties are negative; it has only one use in the atmosphere, and that, again, a negative one. Its sole work here is to neutralise the too active qualities of the Oxygen. Even as water weakens the effects of whiskey in a glass of whiskey and water, so does Nitrogen dilute the Oxygen of the air. So much for Nitrogen, the chief constituent, in point of quantity, of our atmosphere. I may remind you that, although free Nitrogen is such a negative, almost useless, sort of gas, Nitrogen in combination gives us the most positive substances that are known. I need only mention nitro-glycerine and nitro-lignine for you to at once realise this. Now we come to quite a different sort of gas from the mild Nitrogen, the chief constituent in

point of use, the second in point of quantity. I refer, of course, to Oxygen, without which no animal or plant could exist upon this earth. As I have just explained, nearly one-fifth of the atmosphere consists of this gas.

Oxygen is colorless, transparent, and inodorous, in appearance just like Nitrogen or air. If I put jars full of Oxygen, Nitrogen, and air side by side, you could not tell by merely looking at them which was which. So you may, perhaps, ask if these gases are so much alike, how can we tell that the air does contain Oxygen? The mere fact of combustion is a proof. Had there been no Oxygen in the bell-jar full of air we just experimented with, the Phosphorus would not have burned; as it was, it did burn. In other words, the Phosphorus united with the Oxygen, forming dense white fumes of a compound of Phosphorus and Oxygen. When bodies undergo combustion, they unite with Oxygen, giving off heat or light. The presence of Oxygen in the air may also be tested by chemical experiment. It plays a most important part in our lives; indeed, so necessary is it to us that it was formerly called "vital air." By inspiration we draw Oxygen into our lungs; it is absolutely essential to life, and we need fresh supplies each moment. Yet, requisite as it is to our existence, we could not live in an atmosphere of pure Oxygen. In the case of an animal put into an atmosphere of pure Oxygen, it does not immediately suffer, but soon the vital functions are stimulated as if by fever; the pulse and respiration increase; after an hour comes insensibility, then complete coma; death occurs in from six to twelve hours. On examination the heart is found pulsating violently, but the motion of the diaphragm, or partition dividing the upper from the lower part of the trunk, has ceased, the blood is bright in color, and coagulates quickly. All the symptoms I have just noticed may be rapidly alleviated by breathing ordinary air. I do not show you this experiment with an animal, although it is very interesting, because I believe the poor animal experimented upon suffers greatly. What I have just told you is an accepted fact; therefore there is no necessity for me to repeat the experiment here. I can nevertheless demonstrate to you practically how much more active are the properties of pure Oxygen than of Oxygen diluted with Nitrogen. And this I will do on Thursday week, when I come to speak of it under the head of "Water."

Animals cannot live in any gas that is unmixed with Oxygen. Experiments have been tried with gases quite harmless in themselves, but without Oxygen life cannot be sustained. Frogs and snails have been put into pure Hydrogen gas or pure Nitrogen, and have lived twelve or fourteen hours; full grown warm-blooded animals die in two or three minutes; the lungs are found engorged with venous or used-up blood, and they die asphyxiated from the deprivation of Oxygen. Young animals live a little longer because they do not require such a constant supply. But if Oxygen be mixed with Hydrogen in the same proportion as it is found in nature with Nitrogen animals can live and breath without the smallest inconvenience. Without Oxygen there would be no decay. Dead matter,

whether animal or vegetable, unites with Oxygen and disappears from the earth as invisible gases. Considering then how necessary Oxygen is to us, you will not think "vital air" such a bad name for it. I shall now leave Oxygen for the present, when I come to deal with water I shall have occasion to refer again to it.

Now, as to the other gases holding a permanent place in our atmosphere. They are three in number—namely, Aqueous vapor, Carbonic acid and Ammonia; but they occur in exceedingly small quantities compared with the two of which we have been speaking. In 100 volumes of air there are only about 1½ volumes Aqueous vapor; there is a still smaller quantity of Carbonic acid, for 10,000 volumes of air only contain 4 volumes of it, and Ammonia occurs in such a minute proportion that it is very difficult to estimate its exact amount. The quantity of each of these gases in the air varies considerably in different localities and under different circumstances, but, taking an average, the percentage composition of the constant constituents of the atmosphere is as follows:—

$$N = 77{\cdot}95,\ O = 20{\cdot}61,\ H^2O = 1{\cdot}4,\ CO^2 = {\cdot}04.$$

I have not considered Ammonia in this proportion because, as I just now said, there is comparatively so *very* little of it. Then, besides these gases, which are always to be found in a sample of ordinary air, we have occasional constituents such as Nitric acid and Ozone, the amount of which is very variable and dependent on different circumstances, and also gases to be found only in particular localities, such as Sulphur dioxide in the Metropolitan Railway tunnels. Although Aqueous vapor occurs in so small a quantity in the atmosphere I do not suppose any of you have much doubt about its presence there; what little there is of it makes itself very apparent to us. But as I wish where it is possible to lay before you practical proofs of what I say, before commencing my lecture I put some rock salt into a saucer. When I brought this salt I took care to keep it dry; it is now, as you see, quite moist and wet. How has it become so? It has not had water put to it, it has absorbed moisture from the air. Salt is a deliquescent substance, on exposure to the air it absorbs moisture therefrom. At a given temperature air cannot contain more than a certain quantity of moisture, and when it has taken up this maximum quantity it is said to be saturated with Aqueous vapor. At this point the Aqueous vapor is deposited in the form of fog or cloud, or, according to the temperature, it may descend as rain or snow. When Aqueous vapor is deposited during the night in drops upon the surface of plants or other matter exposed to the air it is called dew, and this deposit is caused by the rapid cooling of the earth's surface by radiation after sunset. If the temperature be very low this deposit takes the form of white frost. Masses of Aqueous vapor, more or less dense, are called clouds when they remain suspended in the atmosphere; when they descend to the surface of the earth, or cling to the sides of mountains, they are called fogs or mists. If the temperature of the air falls, a large quantity of Aqueous

vapor assumes a liquid form and descends as rain. Snow is only rain congealed before it falls to the earth. There is some difference of opinion as to how hail is really formed; but it is thought that it results from excessive cold in the atmosphere, produced by sudden changes in the electrical condition of the Aqueous vapor. Hailstones are composed of alternate layers of snow and ice. Hail usually occurs in summer during the hottest part of the day: it rarely falls during the night. The presence of Aqueous vapor in the air is hardly less important to life than Oxygen. More than half the entire weight of a plant consists of water, which is constantly evaporating from the surface of the leaves. Were the air quite dry this vapor would pass off more quickly from the leaves than it could be taken in by the roots; the plant would then droop and dry up. From this we see that moisture in the air is essential to elasticity. Nor is it less important to animals. Water is constantly evaporating from our skin and passing off from our lungs; if the air contained no moisture our bodies would become parched, and we should shrivel up into mummies. We have heard of the terrible effects of the dry hot winds of the deserts upon those who have to traverse those sandy tracts. The air is almost without moisture, the soil without vegetation, and those who have to cross the sandy deserts often fall dying by the way. As it is, since ordinary air does mostly contain moisture, at every inspiration we take in a certain amount which helps to render our bodies supple and elastic. The rain, too, being pure water—and as such a powerful solvent—dissolves or brings with it in falling many atmospheric impurities, which, although injurious to man, are often useful to vegetable growth. Most of you have probably noticed at some time or other how sweet and fresh the air seems after a good shower of rain, and that is due not only to the fact that the earth is cooled and refreshed, but that the air itself is cleansed and purified. Snow also plays no unimportant part in the economy of nature. The winter snow falling on the ground covers it like a mantle protecting vegetation from the destroying frosts and bitter wind. I have now mentioned three gases—Oxygen, Nitrogen, and Aqueous vapor—absolutely essential to an atmosphere in which we are to live. Without Oxygen we could have neither life, fire, nor decay. Without Nitrogen the too ardent properties of the pure Oxygen would destroy us; and water also is equally necessary, not only in the liquid state as we see it in rivers, but as a gas suspended in the air. A fourth gas, which is both a useful and harmful constituent of the atmosphere, is Carbonic acid; but as I shall have to dwell upon this gas at some length I will pass it over for to-night, and give the whole evening to it next Thursday. Ammonia, as I have said, is constantly found in the air, but in minute and varying quantities. It obtains its name from the fact that one of its salts was first discovered near the temple of Jupiter Ammon, in the deserts of Libya. Ammonia is a gas composed of Hydrogen and Nitrogen, and you may remember that, in speaking of Nitrogen, I reminded you that although free Nitrogen was so very negative in all its properties,

Nitrogen in combination generally formed our most active substances; and Ammonia is by no means the least active. Hartshorn, familiar to you all, is only Ammonia dissolved in water, and that, as you know, has at least a tolerably strong smell. Animal and vegetable bodies are composed of Carbon, Hydrogen, Oxygen, and Nitrogen, and when plants or animals die, decay sets in, and these four elements unite with each other and go off into the air as invisible gases. Some of the Hydrogen unites with the Oxygen to form Aqueous vapor, and some with the Nitrogen to form Ammonia; and, therefore, decay is a very constant source of that gas in our atmosphere. Plants require Nitrogen for the formation of their buds and fruits; but I told you some time ago that free Nitrogen was with difficulty made to enter into combination. Therefore, although there is plenty of Nitrogen in the air, plants cannot assimilate it. This being the case, it is from some compound of Nitrogen that plants must obtain what they require, and it is for this purpose that atmospheric Ammonia is most useful—not indeed free Ammonia but Ammoniacal compounds. Another source of the Nitrogen so necessary to plants is Nitric acid, a compound of Hydrogen, Nitrogen, and Oxygen; the aquafortis of commerce is an aqueous solution of Nitric acid. Traces of it are found in the atmosphere in varying quantities; whether it is a constant constituent or not is doubtful. The amount depends principally upon the electrical condition of the air. It is produced by every flash of lightning, and, therefore, is plentiful just after a thunderstorm. Like Ammonia, it is brought down to the plants, for whose growth it is required, by the falling rain and dews. It is as useful a manure to plants as Ammonia. It has been thought that one of the causes of the greater fertility in tropical climates is owing to the presence of so much Nitric acid in the rains falling during the frequently disturbed condition of the atmosphere. Of the occasional constituents of the air Ozone is, perhaps the most remarkable. It was discovered forty years ago by Schönbein. It is merely concentrated Oxygen, but has very different properties from that gas. Our knowledge, however, as to the amount and properties of atmospheric Ozone is very unsatisfactory. Oxygen, as I have already said, has no odor. Ozone has, on the contrary, a very strong smell, and hence its name from ὄζω = I smell. It is said that you may sometimes smell it by the sea-side where it is most plentiful. It is to the presence of this gas in the air over the sea-shore that its invigorating effects are doubtless due. Ozone is never to be found in the air of towns; traces are found in country air, but nowhere is it so abundant as at the sea-side. When I say "abundant" I do not of course mean that there is any great quantity to be found anywhere, but still much of the Ozone contained in the air is to be found near the sea, and for this reason: Ozone, being insoluble, the air passing over the ocean, brings with it its Ozone. Directly, however, this gas comes into contact with putrescent matter it is destroyed. Hence it is not found in the air of towns, especially where much coal is burned, for it is reduced to ordinary Oxygen by the organic emanations and Sulphurous acid

present in such air. Ozone, like Nitric acid, is believed to be generated by the disturbed electrical conditions of the atmosphere, and is largely produced during storms. It is a stong disinfectant; it is also thought by some to affect the mucous membrane, producing colds and catarrhs. Except Carbon dioxide the only other gases we have left to notice are those which occur locally and in the lower strata of the atmosphere. These are really impurities, often harmful and in no sense constant constituents of atmospheric air. I shall only mention one or two of the more important; because were I to describe all the gases which may be found in different localities my task would be endless. In towns there is, of course, the ordinary coal gas, with the smell and appearance of which you are tolerably familiar; in the neighborhood of sulphur springs there occurs a noxious, malodorous gas, called Sulphuretted hydrogen. This is the gas which is so painfully evident to your sense of smell when you break a rotten egg. It is a deadly poison when inhaled in large quantities. If you stir the bottom of a stagnant pool you may see bubbles arising from the surface of the green waters: the gas thus evolved is Marsh gas, so-called because it is always present in marshy, swampy districts. It is also the "fire damp" or "wild fire" of mines, where it is a source of much danger, because mixed with double its volume of air it explodes violently. Enormous quantities are evolved in coal pits; some beds of coal are so saturated with this gas that when they are cut it may be heard oozing from every pore; these are termed by the miners "singing" coals. It is evolved also in large quantities in the petroleum springs. Professor Roscoe says that the holy fire at Baku, on the Caspian Sea, which has been burning from the earliest historical times, is due to Marsh gas mixed with small quantities of other gases. These two or three examples will just serve to illustrate what I mean by occasional constituents of the atmosphere.

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AIR.—II.

CARBON DIOXIDE is so very important a constituent of the atmosphere that I intend to devote the greater part of this evening to it. I make the gas to-night that you may more fully realise the modes in which it is produced naturally. I first prepare some Carbon Dioxide, or Carbonic Acid gas, and then, where it is possible, demonstrate to you practically with the gas we obtain its different properties. I then tell you about several of the natural sources of this most important gas. Lastly, I show you by what means it is withdrawn from the air. I have here some broken marble, which is a compound of lime and Carbon Dioxide. Carbon Dioxide enters into combination with very many substances, forming what are called carbonates. The particular carbonate that we have here is known technically as Calcium Carbonate, and the Carbonic Acid thus combined with other substances may be driven off, if the Carbonate be subjected to the action of heat, or be treated with an acid. Because this gas was found to be a peculiar constituent of Calcium Carbonate and similar substances, and was fixed in them in a solid state, Black, who in 1775 was the first to point out its difference from ordinary air, termed it "fixed air." I have just said that if substances like marble are subjected to heat, or treated with an acid the Carbon Dioxide in them may be driven off. We will take the quicker method, and pour upon the marble a little Hydrochloric Acid, or, as it is generally described in commerce, muriatic acid, or sometimes spirits of salt (spiritus salis). When the gas comes off it will pass through this delivery tube into the pneumatic trough, full of water. Carbonic Acid is only slightly soluble, so we may collect it over water and by that means be more certain to get it free from air than by collecting it by displacement of air. We shall let the first two or three bubbles pass off, as they will be the air that was contained in the delivery tube, and was afterwards forced out by the Carbonic Acid behind it. Now we will put the gas jar over the open end of the delivery tube and the gas will speedily displace all the water in the jar. (Ex.) The jar is no longer filled with water, but is full of Carbon Dioxide gas instead. This, like the other gases previously described, is quite colorless and exactly like air in appearance, but when I come to demonstrate its properties to you, you will see how very different it is from atmospheric air. As just observed, Carbon Dioxide is only slightly soluble. To speak more exactly, water will absorb its own volume of Carbonic Acid, but can be forced to absorb much more by pressure. Now let us try its

powers of combustion. Will it itself burn? will it suffer other bodies to burn in it? I put a lighted taper into this jar full of gas. The gas does not ignite and the taper goes out; therefore Carbonic Acid is neither combustible nor a supporter of combustion. Nor does it support respiration. Animals thrown into Carbonic Acid gas become insensible and die of suffocation. (Ex.) It does not exactly poison animals, since it is being constantly taken into the lungs and given out by them; but an animal will suffocate in an atmosphere of Carbon Dioxide because there is no free Oxygen and, as explained last week, a certain amount of Oxygen is absolutely necessary to the maintenance of animal life. You see this blue liquid. It is what is called a solution of litmus—a vegetable solution. That which I hold up to you is, as you see, quite dark blue in color. I pour a little into this Carbonic Acid and it turns a very decided red. The fact of its turning a solution of vegetable color matter red is proof even to the veriest novice in the study of Chemistry that this gas in the presence of moisture is acid—hence its name Carbonic Acid gas; a very bad name for it, by-the-bye, because the dry gas itself is not acid; it is only acid in the presence of moisture. Carbonic Acid has still another property, and a most remarkable one peculiar to this gas alone. Water will dissolve a certain amount of lime and still be quite clear. This solution of lime is called lime-water. If we add to lime-water a little Carbonic Acid the liquid does not remain clear, but becomes quite turbid and has a milky appearance. The Carbon Dioxide has united with the lime dissolved in the water and has formed this chalky precipitate of Calcium Carbonate. If more Carbonic Acid be passed into the solution the precipitate redissolves. This remarkable characteristic is very useful in testing for this gas. Now as to its weight. If we take two jars of equal capacity and fill one with air and the other with Carbonic Acid and put them on the two pans of a scale, we find the scale with the Carbonic Acid fall. It is much heavier than the ordinary air, nearly half as heavy again. It is easy to show you that it is heavier than air, because when it is poured out of the jar it of course sinks. It may be poured from one jar to another like water. (Ex.) That you may yourselves see that it is Carbonic Acid thus passing into the second jar, I have put a little lime-water into it. When the gas reaches the lime-water we shall see it become milky and turbid. Of course if Carbonic Acid were lighter than air it would not sink in this fashion, and we should have to wait a long while before the lime-water would change its appearance. That I might thus prove to you that it was heavier than air, I passed over the question of its weight until I had explained its other properties. By this time you will realise how very different Carbonic Acid is from ordinary air or any of the gases we were talking about last week.

There are several ways in which it is produced in nature, of which the chief, perhaps, is combustion. Let me again remind you that combustion means union with Oxygen; Carbon burning or uniting with Oxygen forms Carbon Dioxide. There is an enormous quantity of

Carbon in nature, organic matter always contains Carbon in greater or less quantities, and when we remember that organic matter includes substances derived from both the animal and vegetable kingdoms we soon understand what a very large amount of Carbon there must be in the world. Coal is principally composed of Carbon, and candles also contain a large amount. What is commonly called black lead in your pencils is pure Carbon, so also is the diamond. If you burn any one of these—not that I wish to insinuate that you are in the habit of burning diamonds, for that indeed would be a more difficult matter than perhaps some of you think—but supposing you succeeded in burning a diamond or any other form of Carbon, you would be generating Carbon Dioxide. It is formed every day by the fires burning in your grates and the gas burning in your rooms. I will show you a small experiment that will illustrate to you very clearly the production of Carbon Dioxide by combustion. I have here a glass jar containing a little lime water, which is as you see quite clear; I put a lighted candle into the jar; the candle will burn as long as there is sufficient Oxygen for its combustion; when the Oxygen is used up the light will go out, just as you saw the lighted Phosphorus extinguished last week in the bell jar. Now you see the lime water in the jar is no longer clear, but is all turbid and cloudy, and that of course indicates the presence of Carbonic Acid.

It is rather travelling away from my subject, but in passing I may notice that the experiment showing the production of Carbonic Acid by combustion is also a very fine experiment to illustrate the indestructibility of matter. This flask, if we weighed it, we should find would have exactly the same weight after the experiment as before it, and yet some of the candle has apparently disappeared. The explanation is that a candle is composed chiefly of Carbon and Hydrogen. During the process of combustion these unite with the Oxygen of the air in this jar to form Carbonic Acid and steam. That Carbonic Acid is formed I have already proved to you, and the steam you may see hanging round the sides of the jar.

Another very fruitful source of the existence of Carbonic Acid in our atmosphere is respiration. Respiration is only another form of combustion. Every animal, I repeat, has a certain amount of Carbon in its composition. When we exert ourselves in any way this Carbon unites with the Oxygen we have taken in from the air and forms Carbon Dioxide. This is given off from the lungs into the air in the process of respiration. This again I can show to you practically with the help of the ever useful lime water. This test tube is about half full of the clear liquid, I will now breathe through this long tube so that expired air from my lungs may pass directly into the lime water. The lime water, as you see, has become quite turbid, therefore we know that Carbonic Acid is produced by respiration. To show that there is a great quantity produced in the room at the present moment (both by respiration and combustion) I set a dish of lime water in the room just before I began my lecture. When I have finished those who care to look at it will

probably see a cloudy film upon the surface of the liquid. Respiration produces several changes in atmospheric air. Firstly: The air is warmed by it, because however low the temperature of inspired air may be it nearly acquires that of the blood before it is expelled from the lungs. Secondly: The amount of Carbonic Acid and Aqueous vapor is increased. The average amount of Carbonic Acid in atmospheric air is four volumes in 10,000. After the air has passed through the lungs it contains as much as four per cent. of Carbonic Acid. A healthy man we are told spoils 726 cubic feet of air in 24 hours. Absolutely *spoils* that quantity of air, because when the air contains a certain amount of Carbonic Acid it becomes irrespirable. Last week I told you that the air contained varying amounts of aqueous vapor, and that it was capable of containing a certain quantity, and that when it contained this maximum quantity it was said to be saturated. In whatever condition as regards moisture the air is when it is taken into the lungs, except in cases of hurried breathing, the expired air is nearly always saturated with watery vapor. Thirdly: There is always less Oxygen in respired air than in the same air before respiration, and this diminution is generally in proportion to the increase of Carbonic Acid. Organic matter is also given off from the lungs by respiration. Since we find the air so changed and vitiated by its passage through the lungs it is very clear that if the same atmosphere be breathed again and again, these deleterious constituents will be constantly increased, and the quantity of the life-supporting Oxygen diminished until fatal results ensue. Professor Roscoe says that there are four things which render a room unfit for habitation. First: Excessive quantity of the oxides of Carbon and other poisonous gases. Second: Too little or too much Aqueous vapor in the air. Third: The presence of organic putrescent bodies from the decomposition of animal or vegetable matter; and Fourth: Inconvenient elevation of temperature. Any one of these, he says, is injurious for any length of time, and in general we find them all together. If the air contains 10 per cent. of Carbonic Acid and half the usual quantity of Oxygen has also disappeared, it is fatal to man. Of course, long before this point is reached, unpleasant sensations are experienced. One begins with headache, and is conscious of a fullness in the temples; a sense of oppression follows, then faintness, drowsiness, insensibility, coma, death. Of course, we do not often get such an excess of Carbonic Acid in our dwelling-rooms in England, except when a person commits suicide by burning Charcoal; but it is no uncommon cause of death during the winter time in France and Germany, where Carbonic Acid is largely produced in the stoves used there for warming rooms. In England we often feel the preliminary sensations, especially in crowded assemblies, whence people are frequently carried in a fainting condition. The only way to reduce this evil is to have thorough ventilation, thus preventing the accumulation of noxious gases. Not only animals, but plants, too, give off Carbonic Acid in respiring.

Decay, we noted last week, is a constant source of Ammonia;

so it is also of Carbon Dioxide. Like respiration, decay is only another form of combustion. Here, again, the Carbon of the animal unites with the Oxygen of the air and forms Carbon Dioxide. I do not intend to prove this to you practically, as it is anything but a sweet-smelling experiment. Another source of Carbon Dioxide in the atmosphere is fermentation; it is given off in the fermentation of wine, beer, etc. About a year and a half ago, I read of three men suffocated—I think in Italy—by the Carbonic Acid produced in wine-making. One man went down the steps into the vat to see if the fermentation was going on properly, I presume; as he seemed somewhat long in coming up, his two companions went down to ascertain what was the matter. Not one of these men came up alive; they were all suffocated by Carbonic Acid gas. The next great source of Carbonic Acid is the manufacture of lime. Lime is, as most of you know, obtained from chalk; and those who have dwelt in chalky districts will remember that a limekiln is no unfamiliar sight. You can hardly take an hour's walk over the South Downs without seeing one or two kilns. I cannot say that I think they add much to the beauty of the scenery. Chalk, which is of exactly the same nature as the marble we were using a short time ago, is put into a kiln and heated to a red heat by means of coal mixed with stone; the Carbonic Acid is evolved, escaping into the air, and the lime is raked out from the bottom of the kiln. In the winter time it is no rare occurrence for a tramp to be found dead near a lime-kiln. The weary wanderer, attracted by the glowing kiln, not thinking of any danger, finds himself a warm corner as close to the fires as he can. Overcome often by cold and fatigue, soothed by the warmth and rendered drowsy by the treacherous gas, he falls asleep to wake no more.

Carbonic Acid gas is also found in old wells, cellars, coal-pits, and craters. When it occurs in this fashion, it is commonly known as choke-damp. We saw a few minutes ago that it would not support combustion. Therefore, when it is necessary for men to descend into any old well or cellar, you may often see them send down a candle first; if the candle goes out, then the men know it is dangerous for them to go down. I told you last week in what enormous quantities Marsh Gas occurs in coal mines. This gas has been generated in that decay which has resulted in the formation of the coal, and is present in these pits in a highly compressed condition. If this gas once unites with Oxygen, whether through a carelessly-exposed light or other means, or if, through bad ventilation, there should be an insufficient supply of air, a terrific explosion results; and, mark, if the poor miner has by any good fortune escaped from the explosion with his life, he has the *after* or *choke-damp* to face. The fire-damp uniting with the Oxygen produces the explosion; and, moreover, this union—by the formation of such an enormous quantity of Carbon Dioxide—so vitiates the atmosphere as to render it irrespirable. This is what makes it so difficult to descend into the pit after such an explosion until, by sufficient

ventilation, some of the Carbon Dioxide has been expelled. The only way to prevent such horrible disasters is to hinder, by most thorough ventilation, the accumulation of the fire-damp. Carbonic Acid occurs in old craters near Vichy and Hauterive, in Auvergne, where it is turned to some use. It is employed in the manufacture of white lead. It is the evolution of this gas which has made so famous the Poison Valley in Java, another old crater, and the Grotto del Cave, near Naples, where we are told that the cave is so curiously formed that the heavy gas, coming up from fissures in the floor of the cave two or three feet below the mouth, collects to this depth and immediately suffocates a small animal thrown into it, while a man may stand upright in it, and, breathing the pure air above, remain unharmed.

Some of you will, perhaps, be thinking if from all these sources Carbon Dioxide is being constantly poured forth into the atmosphere, and if it is such a noxious gas, how is it we are all alive at the present moment? That is just what I am going to explain to you. Do not forget that which is death to one may be life to another. Excess of Carbonic Acid is death to the animal; but, strangely enough, if it were not present in the atmosphere, our vegetable kingdom could not exist. It is the Carbonic Acid gas in the air that forms the principal food for plants. The chief source of the Carbon necessary for the formation of the tissues of plants is the decomposition of Carbonic Acid contained in atmospheric air. It is believed that the green color matter of plants only, the living chlorophyll, has the power of decomposing this gas. The decomposition takes place in the presence of sunlight; at night-time, when all is dark, the operation ceases. The Carbon is taken up by the plant for its own growth, and the Oxygen is rejected. This fixation of the Carbon by the plant produces two good results, it takes Carbon Dioxide from the air and gives back to it free Oxygen. It is quite a mistaken idea—gradually dying out, indeed, but still held by some people—that plants are harmful in a sick room. Flowers may be, if they have a strong perfume, but in the day-time instead of plants being injurious they are beneficial. At night-time plants cease to decompose Carbonic Acid, but on the contrary give it out in the process of respiration. Respiration goes on both day and night, but although the assimilation of Carbon takes place by day only, the Carbonic Acid thus decomposed is greatly in excess of that produced. Light and heat are absolutely necessary to the decomposition of Carbonic Acid, not necessarily solar light, for it is said that light from other sources than the sun has been observed to have the same effect, provided that the intensity and refrangibility of the rays are the same. In general both sides of the leaf of the plant take part in the process although with different energy. Plants having no chlorophyll do not possess the power of taking up the Carbon from the Carbonic Acid of the atmosphere. But as such plants exist, it is quite evident that if they cannot obtain their food directly from the air they must get it from some other source. These plants, a *botanist would tell* you, either grow in or on animals or other

plants, as parasites, and obtain their Carbon from them, or live on decomposing organic substances, and absorb their organic constitutents before they are completely decomposed. The solubility of Carbon Dioxide enables water plants to get their share, which they require as much as the land plants. If you consider how much green color matter there is in nature, how many leaves upon a single oak tree, and then if you think for what a large proportion of the day we have the solar light you will readily understand how it is that, notwithstanding its numerous sources, Carbonic Acid does not perceptibly increase. I told you that there were about four volumes of Carbonic Acid in 10,000 of air, that is to say ordinary country air; very pure country air will contain a little less, whilst the air of towns, of course, contains more. If it contained much more it would be injurious to animal life. Air which contains seven volumes in 10,000 is injurious, and in towns where much coal is burnt the amount does sometimes rise to as much as six or seven in 10,000. Over the sea there is less Carbon Dioxide, about three volumes in 10,000. Dr. Angus Smith made a large number of experiments in order to find out the amount of Carbon Dioxide in the atmosphere of different localities. With the exception of mines he found the most Carbon Dioxide in theatres and workshops, and the least on the Scottish Hills. Making investigations as to the air of mines, Dr. Smith tells us in his work upon "Air and Rain" that he found the air in the mines of Cornwall the worst. He was there told by a miner that the men had worked in spots where it was impossible to remain above ten minutes at a time, and where every man in his turn fell down, and the candles went out. *Nevertheless they went to their work and took their turns.* Dr. Angus Smith also made a number of experiments to ascertain the amount of Oxygen in different places, and, although the proportion of Oxygen seems more constant than that of Carbon Dioxide, still he found most Oxygen in the air of Scotland, by the sea shore, on the open heath, and on the tops of hills; he found the least Oxygen—always excepting mines—in the atmosphere of the Court of Queen's Bench in winter time. He made his experiment upon the air about eight feet from the door.

Now, to consider what places we derive most benefits from visiting, and why? If what I have been saying is correct, the sea shore is healthier than inland districts, because there we have that great oxidizing agent, Ozone, brought in by the sea breezes, and we get there the smallest quantity of Carbon Dioxide. It is hardly wonderful that townfolk, coming out of an atmosphere impregnated with Carbon Dioxide into an atmosphere containing its proper amount of Oxygen, should derive so much benefit, should take in so much health from a visit to the sea-side. You feel better from a stay in the country, but it does not seem to produce quite the same good effect as a few days at the sea-side, and this probably for two reasons: 1st. There is more Carbon Dioxide in the air; and 2nd, little or no Ozone. The way to have healthy houses is to prevent accumulation of Carbon Dioxide and other noxious gases; for this you must have thorough ventilation.

Do not be afraid to throw open the windows at least once a day, even in winter time. Be thoroughly cleanly, for decaying organic matter is a fruitful source not only of Carbon Dioxide but of gases still more injurious. If you live in a quarter of London where the air is very impure through bad drainage or anyone of the scores of other causes which bring disease, use some disinfectant, some oxidizing agent. One of the best I know of is Permanganate of Potash; it is very cheap, threepennyworth will make about a gallon, and it is the basis of Condy's Fluid, only that is dear. The objection to disinfectants as a rule is that they smell very unpleasantly, but Permanganate of Potash has no smell whatever. By using this or some such disinfectant the impure particles in the air are oxidised and their harmful tendencies destroyed. It is also advisable to keep, if possible, some green-leaved plants in the rooms, since, as we have just seen during the day-time, their use is twofold, they remove the Carbon Dioxide from, and give back Oxygen to the atmosphere.

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WATER.—I.

In the previous lectures we discussed one of Aristotle's Elements, viz., Air, now proved conclusively to be a mixture. To-night we take up another of the so-called Elements, Water, which, a century ago, Cavendish and Lavoisier (that celebrated Frenchman who has done so much for Chemistry) discovered was no element, but a compound of Hydrogen and Oxygen. You shall see for yourselves that this was a real discovery, and you shall also see how very unlike are the two gases, which, united together in the proportion of 2 of Hydrogen to 1 of Oxygen, form the liquid commonly known as Water. We will take the gases separately first, and remark their different properties before we look at them in combination.

Oxygen is a colorless, transparent gas, tasteless and inodorous. It is excessively difficult to liquefy, and was long called one of the "permanent" gases—six gases, *i.e.*, Oxygen, Hydrogen, Nitrogen, Carbon Monoxide, Marsh Gas, and Nitric Oxide—which it was thought impossible to liquefy. In 1877 two men, by totally different methods, succeeded simultaneously in reducing Oxygen to the liquid state. Messrs Roscoe and Schorlemmer say of this:—"It is difficult, on reading the description of these experiments, to know which to admire most, the ingenious and well-adapted arrangement of the apparatus employed by Pictet, or the singular simplicity of that used by Cailletet. The latter gentleman is one of the greatest of French ironmasters, whilst the former is largely engaged as a manufacturer of ice-making machinery, and the experience and practical knowledge gained by each in his own business have materially assisted to bring about one of the most interesting results in the annals of scientific discovery." Oxygen is a trifle heavier than air, and is slightly soluble in water. All bodies which burn in the air will burn with increased brilliancy in Oxygen. To illustrate this we will ignite some Phosphorus and Sulphur. They both burn well enough in the air, as you see. Now we will put them into Oxygen (Ex.) See with what dazzling brilliancy they now burn. Having seen this, you can realise how much more active pure Oxygen is than ordinary air. Not only will such bodies as Sulphur and Phosphorus burn with increased brilliancy in Oxygen, but many substances which do not burn easily in the air burn well in Oxygen. Take, for instance, iron wire. Hold the wire in the flame of the lamp; it does not burn. But, if made red hot and then plunged into the jar of Oxygen, it burns well. In burning, Oxygen unites with the substances burnt, forming oxides, and it takes its name

from the fact that many of these oxides have acid properties, Oxygen being derived from two Greek words, ὀξυς = sour, and γενναω = I produce.

Hydrogen (from ʽυδορ = water, and γενναω = I produce) is like Oxygen, a colorless, transparent, inodorous and tasteless gas, and also extremely difficult to liquefy. It was indeed the very last gas to be liquefied. All efforts to reduce it to the liquid condition had been failures until M. Pictet succeeded in 1878. The characteristics it then evinced have led to the belief that Hydrogen is a metal in the gaseous condition. When the liquid Hydrogen was delivered into the receiver it appeared steel blue in color and fell with a rattling sound resembling the noise made by the falling of hail or small shot. Observe how different a compound may be from its constituent parts. Oxygen and Hydrogen, gases difficult to liquefy. Water produced by their combination—a liquid normally, and passing easily into the gaseous or solid states. Hydrogen is the lightest body known, air is 14½ times as heavy as Hydrogen. To illustrate to you its exceeding lightness we filled this balloon with Hydrogen gas to-day. When I let it out of my hand you will see how it ascends to the roof. It ascends to the highest point and remains there. The large balloons used by æronauts used to be filled with Hydrogen gas, but it was found too expensive, and now coal gas is generally employed. Hydrogen is very slightly soluble in water, less so than Oxygen. Now as to its powers of combustion. If I put a lighted taper into this jar of Hydrogen gas, the gas ignites as you see—(Ex.)—with an explosion more or less violent and burns with a blue flame. Hence it is clear that Hydrogen is combustible. But notice that the taper is extinguished. Hydrogen will not support ordinary combustion. There is one other extraordinary property that I may mention. Pure Hydrogen may be inhaled for some time without danger, but it affects the voice most curiously, weakening it, and making it of higher pitch.

Again, let me remind you that combustion generally means union with Oxygen. Oxygen uniting with other bodies, forms oxides. In this case uniting with Hydrogen, Hydrogen Oxide is formed, and Hydrogen Oxide is only the scientific name for ice, water, or steam. After we have put a light into a jar containing Hydrogen gas you can see the steam or Hydrogen Oxide hanging round the sides of the jar.

It is difficult to believe that water which looks so simple, so ordinary, should be the product of the union of these two remarkable gases, but so it is, and I will prove it to you in two ways; by synthesis and analysis.

By synthesis (from συν = together, and τιθεμι = I place) is meant the putting together of things, therefore it is my business to demonstrate to you the formation of Hydrogen Oxide from a mixture of Hydrogen and Oxygen. This test tube contains such a mixture in the proportions of $\frac{2}{3}$ Hydrogen to $\frac{1}{3}$ Oxygen. A light is brought *into contact with the* gases. (Explosion.) You may see the steam

hanging round the tube. The gases may be made to unite without bringing a flame near them by means of an electric spark.

By analysis (from *ανα* = up and *λυω* = I free) is meant the reducing of a compound into its elementary parts. We have, then, to break up water into Hydrogen and Oxygen. This may be done by electrolysis. We have here a Bunsen's battery with its two electric wires dipping into the water in the pneumatic trough, and the two poles brought under two gas jars. This experiment generally takes a very long while, so I started it before I began my lecture. From the negative pole is given off the positive radicle Hydrogen, from the positive pole the negative radicle Oxygen. By radicle is meant the basis of a compound, an indivisible and transferable body; every compound consists of two radicles, one positive and one negative. From what you have heard you will think that we ought to collect twice as much Hydrogen as Oxygen, but in reality more Hydrogen comes off than that, because not only is Oxygen more soluble but it has also a tendency to unite with the copper of which the electric wire is composed. To avoid this a Platinum plate is generally fastened to the end of the electric wire, and although some of the Oxygen will unite with the Platinum it combines with it less readily than with the Copper. I will just show you the effect of a light on the gases contained in these jars, so that you may see that they are really Hydrogen and Oxygen. (Ex.)

Now that we have decided its composition we may proceed to discuss the properties of water itself. Hydrogen Oxide occurs in nature in three forms, solid as ice, liquid as water, and gaseous as steam. The only particular property of ice to which I need draw your attention is that it is lighter than water, and this property plays a very important part in nature, as I will show you later on.

Pure water is a clear tasteless liquid; a small quantity appears colorless, but when seen in bulk it is of a blue or bluish green color. It is 770 times as heavy as air; 1 litre of air weighs a little more than $1\frac{1}{4}$ grams, whilst a litre of water weighs 1,000 grams. Translated into our barbaric system of weights and measures, it amounts to something like this: 61 cubic inches of air weigh about $18\frac{1}{4}$ grains, and 61 cubic inches of water weigh $2\frac{1}{5}$ lbs. Water is a bad conductor of heat; it may be boiled at the surface without becoming hot below. It is even a worse conductor of electricity. Almost an incompressible fluid, one million volumes of water subjected to twice the ordinary atmospheric pressure become less only by fifty volumes. It is also worth while noticing the extreme mobility of aqueous particles. If water fell from the clouds to the earth like ice or stone would fall, think of the mischief and destruction which would ensue! Owing, however, to the resistance of the air and the mobility of the particles, water—save under exceptional circumstances—falls gently and lightly to the earth. Pure water is a better solvent than any other known; it possesses this power in such a high degree that it is often called the universal solvent. It dissolves solids, liquids and gases. Hot water generally dissolves *solids and liquids* more freely than cold, but to that rule we have two

exceptions. Common salt is not more soluble in hot than in cold water, and lime is nearly twice as soluble in cold water as it is in hot. Water has even been made to dissolve glass. It is in consequence of this enormous solvent power that springs always partake of the character of the soil through which they pass. I cannot deal with the properties of water and omit to speak of the gases it takes into solution. All gases are soluble in water, but not all in the same degree; the solubility depends on the nature of the gas and the temperature and pressure at the time of absorption. Generally a gas is less soluble in hot than in cold water. It is to the gases contained in all water exposed to the air, and not to those gases which the water is forced to absorb by abnormal pressure, that I want to bring your notice. It is to the atmospheric gases, Oxygen, Nitrogen and Carbon Dioxide, that I allude. Marine animals depend upon this dissolved Oxygen for their life. In pure water Oxygen and Nitrogen occur in the proportion of a trifle more than 1 of Oxygen to 2 of Nitrogen. If the water contains organic matter the proportion is different, because the Oxygen is used up in oxidizing the oxidizable matter. For instance, Miller made several analyses of Thames water collected at different places above and below London. At Kingston the water was pure, and contained 1 of Oxygen to 2 of Nitrogen; at Greenwich the water contained 1 of Oxygen to 60 of Nitrogen; at Erith the water, becoming purified again, contained 1 of Oxygen to 8 of Nitrogen. Dr. W. B. Carpenter, in speaking of the muddy state of the bottom water of the Mediterranean as being unfavorable to animal life, says that there is another condition of that water still more unfavorable, namely, the deficiency of Oxygen. Analysis showed that the water brought up from the great depths of the Mediterranean contained only about 5 per cent. Oxygen and 5 per cent. Nitrogen, the remaining 60 per cent. being Carbon Dioxide. In the deep water of the Atlantic the average per centage of Oxygen was about 20 and Carbon Dioxide between 30 and 40, "even," Dr. Carpenter adds, "this large proportion of Carbonic Acid not appearing prejudicial to the life of Marine Invertebrata so long as Oxygen was present in sufficient proportion." Water possesses a remarkable power of cooling. Taken by an animal internally and externally in any climate, it cools more than an equal weight of any substance we could employ. Of course, water is both incombustible and a non-supporter of combustion. If you heat it to 100° C. (212° F.) it passes into the gaseous condition; if you cool it down to 0° C. (32° F.) it solidifies. Pure water is absolutely neutral; it is neither acid, nor alkaline.

The only pure water is distilled water. In order to get water pure you must bring it to the gaseous condition, and then condense it; by that means only can you get pure water, and even then, probably, it will not be *absolutely* pure; volatile impurities, such as Ammonia, will be carried over with the steam. These would have to be withdrawn by chemical agencies, about which I have not time to tell you now. Distillation is, however, a very simple process,

and if at any time you should require pure water you can obtain it by the method you will now see. Take a retort and put into the bulb your impure water. I have taken colored water in order that the difference between distilled and undistilled water may be more apparent to you. Put a flame under the bulb, and as the water boils the steam will pass down the neck of the retort. Keep this cool and the steam will condense, running into the receiver as pure water. (Ex.) If you taste distilled water you will not like it, because it is so very insipid: being pure it has no taste.

Not one of the various forms of water we meet with in nature is pure, but the least impure is Rain or Snow water. That, however, contains air, and collects many atmospheric impurities in its passage to the earth. It is estimated that Rain water contains 2½ per cent. of atmospheric impurities. After Rain water the least impure is Spring water, but this contains a large quantity of inorganic matter. When the rain touches the earth it dissolves the soluble constituents of the earth's crust; the water penetrating into the ground becomes more and more impure from impurities varying with the locality. The springs thus formed contain a large quantity of mineral impurities. When these impurities do not affect the taste the waters are termed *fresh*, when the waters possess a peculiar taste or medicinal qualities they are termed *mineral* waters, and these I shall refer to again presently. The principal impurities of ordinary Spring water are: Carbonic acid, whence the water derives its bright, sparkling appearance and fresh taste; Chalk (Calcium Carbonate) held in solution by the presence of Carbonic acid; Common Salt (Sodium Chloride) and Gypsum (Calcium Sulphate). Some of these springs are always flowing, and are then called perennial springs. Some cease to flow during the dry season, and others rise and fall at particular periods of the day or year, either without any visible cause, like the fountain of Como which rises and falls every hour; or else they sometimes rise and fall with the tides, although often far from the sea. There are tide springs in England—at Torbay and Buxton.

The springs run into the Rivers, and as they flow along gather fresh impure matter. Hence rivers contain not only the organic impurities peculiar to them, but also the inorganic impurities collected by the springs in their passage along the earth to the rivers. Of course, all rivers contain an enormous quantity of animal and vegetable living things, and if there were not some process of natural purification, rivers would be a fruitful source of disease. But, as I have already said and must again repeat, when organic bodies decay the four elements—Carbon, Hydrogen, Oxygen, and Nitrogen—of which they are composed, unite with one another to form gases and mix with the atmosphere, or are held in solution in the water.

The rivers in turn run into the Sea, and the sea not only contains organic impurities peculiar to it, but the river inorganic impurities and the Halogen salts—so-called from ʽαλς = sea, and γενναω = I produce—because they may always be obtained from the sea. These are the *Chlorides*, *Bromides*, Iodides, and Fluorides, the splendid

medicinal qualities of some of which are now becoming widely recognised. The Iodides and Bromides of Potassium and Sodium are specially useful in nervous diseases. Traces of nearly every mineral have been found in the sea. Dr. Bernays says that "the ship, as it sails through the ocean, actually receives on its copper bottom deposits of silver and lead, and attempts have been made to make use of the sea as a source of silver, but the quantity derived from it has never proved sufficient to make the experiment remunerative." It is to an oxide of iron that the red color of the coral is due. The average quantity of solid matter found in the sea is about 36 grams in 1,000 grams of sea-water, and the amount is tolerably constant when the water is collected far from land. If you wish to prove for yourselves what a large amount of solid matter there is in sea-water, the next time you go to the sea-side bring away a little, or get some from the Great Eastern Co., and put it into a capsule or other vessel over the gas and evaporate it to dryness; the solid matter will be left behind. Sea-water undergoes a constant cleansing from its organic impurities in the same way as river-water. For the benefit of those who are fond of sea-bathing and like to know the temperature of the sea compared with that of the atmosphere, I have taken the following observations from Mr. Hughes's work on "Physical Geography:"—1. The temperature of the ocean is lower at mid-day than the atmosphere in the shade. 2. Morning and evening the temperature of both is usually the same. 3. Water over a sand-bank is colder than where it is deeper.

When you wish to think of the color of water it will not do to think of the sea, because the various impurities found in the sea lend to it many wonderful shades and colors. Those most familiar to us are the deep blue and green shades, but there is a Vermillion Sea at California, which takes its name from its extraordinary color, and in other parts of the world there are red, yellow, black and white seas. The waters of the ocean are constantly evaporating, and wherever evaporation is greatest the sea is saltest. At the equator the sea is salter than in the temperate zones. At a distance from land the water is salter than close to the shore, because there the fresh water of the inflowing rivers is apparent. The salt obtained by the evaporation of sea-water is known as *bay* salt, and is considered best for the preservation of meat. When sea-water freezes most of the salt remains unfrozen, and the ice is nearly free from salt. There is a great difference in the saltness of different seas: the British Channel is five times as salt as the Baltic Sea, and the Dead Sea is nearly eleven times as salt as the British Channel. Although the seas are not uniformly saline, taking them as a whole there is no perceptible increase of saline matter. This is partly because the salts are used up in the formation of shell, etc., and partly because of the constant influx of fresh water brought by the inflowing rivers. Evaporation is always going on; the vapor thus arising from the sea forms clouds. These condense and fall to the earth as rain. The rain penetrates the ground and springs arise. The waters from the springs run along the surface of the

earth as little rivulets or streams. Many of these flow into a wide basin and form a lake, or fall into one somewhat larger than the rest, and this is called a river. The river flowing onward, and widening as it flows, at last reaches the mighty ocean, and the same process is repeated again and again, thus keeping up a constant sequence.

Spring waters containing some mineral in excess, and therefore possessing a striking taste or other quality which renders them remarkable, are, as I before mentioned, called *mineral*, in order to distinguish them from the ordinary or fresh-water springs. There are four kinds of mineral springs :—

1st. *The effervescent or carbonated waters.* These contain Carbonic acid in excess, and are found at Spa, Selters, Pyrmont, Apollinaris, and a host of other places. We can prove the presence of Carbonic acid in any substance: 1st. By its extinguishing a light, and 2nd. By its turning lime water milky. We have a bottle of Seltzer water here, and we will see for ourselves whether it does really contain Carbonic acid gas. When it is opened I will hold a lighted taper over it. (Ex.) The taper goes out. This proves to us that the gas coming out of the bottle is a non-supporter of combustion. Now, I pour a little Seltzer water into this clear lime water. (Ex.) The lime water has become cloudy, therefore we know that the gas is Carbonic acid. That which we have here is, of course, the ordinary Seltzer water, manufactured in England, where the Carbon Dioxide is forced in by pressure; but you may in the same manner prove the presence of Carbon Dioxide in the natural waters. These effervescing waters are much sought after on account of their refreshing and stimulating qualities.

2nd. *The saline waters.* These contain excess of different salts, the principal of which are: 1. Sodium Sulphate, commonly known as Glauber's salts, or Salt cake, useful for medicinal purposes. The waters at Marienbad and Friedrichshall contain large quantities of this salt. 2. Magnesium Sulphate or Epsom Salts, at Epsom, and other places. Magnesium Sulphate is used as a medicine and for dyeing. 3. Sodium Chloride or Common salt, familiar to everyone. It is found in almost every mineral spring, notably at Droitwich, in Worcestershire, where the brine is said to contain 2760 grains to the pint. I can give you no simple method of finding which of these salts you might have in sample of saline water. Probably you would find all three together with one greatly in excess of the others. You would almost certainly find Sodium Chloride in any specimen of natural salt-water.

3rd. *The Chalybeate springs.* These contain Iron salts in excess, principally Carbonate and Sulphate of Iron, and derive their name from χαλυψ = steel. Iron waters are considered excellent tonics and astringents. The springs best known to you will be those at Brighton and Tunbridge Wells. If you wish to know whether any particular water contains Iron, add to a sample a few drops of Tincture of Nut Galls, and if Iron be present the water will turn black as ink, just as this has done. (Ex.)

4th. *The Sulphur springs.* These contain Sulphuretted Hydrogen in excess, and the waters are very useful in cases of skin disease. Those at Harrogate and Moffat are widely known. You do not need a test to discover the presence of Sulphuretted Hydrogen in water; the smell is sufficient.

Besides the mineral springs, we have also *thermal* or hot springs. One of the hottest known is to be found at Trincheras, in Venezuela. The temperature of this spring reaches 97° C. or $206\frac{3}{5}$° F. You have all heard of the boiling springs of Iceland, the terrible Geysers, which throw out jets of water, sometimes to the height of 200 feet.

Mineral baths are sometimes recommended for invalids, who indeed do not seem to derive so much benefit from bathing in mineral waters—apart from the benefit always to be obtained in bathing—as in drinking them. The hot springs at Bath once had a great reputation; the waters there contain Calcium Sulphate and Iron salts. There are some waters at Leuk, in Switzerland with a temperature of about 110° F., where people are apparently so comfortable that they do not leave the bath even for lunch; it is brought to them there. Of course bathing is an absolute necessity for everyone; and of all baths the swimming bath is the best, especially for people whose occupation gives them little or no physical exertion. In swimming every muscle of the body is exercised; and the healthiest of all swimming baths is the open sea, where not only do you get extra exercise in the form of a little knocking about by waves, but while you are bathing you are inhaling the purest possible air.

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WATER.—II.

LAST week we noticed a particular property of ice which plays a most important part in Nature, and it is that property which we are now about to consider.

Most bodies expand when heated and contract on cooling. Water forms a remarkable exception to the general rule. Heated from 0° C. to 4° C (32° F. to $39\frac{1}{5}$° F.) water contracts, cooled from 4° to 0° it expands. Above 4° water follows the general law, below 4° it continues growing lighter until it freezes. Hence it is said that the point of maximum density of water is 4°, or that a given bulk of water at 4° will weigh more than at any other temperature. If water continued to become heavier on cooling through the degrees below 4° there would be a constant circulation, the heavier and cooler water at the surface would continue to sink, giving place to the warmer and lighter water from below, until the whole mass was frozen, sometimes such an enormous mass that the returning summer's heat could not possibly suffice to melt it. But this is not what does happen. When the water reaches 4° it expands and bulk for bulk becomes lighter; it no longer sinks, but, remaining on the surface, grows colder and colder until it freezes, the water beneath the surface rarely reaching a lower temperature than 4°. In very severe weather ponds and shallow lakes often become one solid mass, but seas and deep lakes never freeze throughout. If all the rivers, lakes and seas froze up entirely, the fish and plants contained in them would die; all aquatic animal and vegetable life would be destroyed every winter. As it is, it is only shallow waters that occasionally solidify throughout and in which fish and plants are frozen to death; in seas and deep lakes the bulk of the water rarely gets below the temperature of 4°. After severe weather your water-pipes burst. You blame the thaw for what is in reality the effect of the frost. The water expands on freezing and bursts the pipe. You do not notice it then, because the water is in a solid state; but directly warmer weather sets in the ice melts, and a rush of water reveals the mischief done. The only way to prevent this is to have the pipes indoors, or if you are obliged to have them outside, to cover them with some non-conducting material. If this is impossible, I am afraid that in very severe winters you must look forward to the bursting of your water-pipes; but in future remember to blame the frost and not the thaw. Those of you who have gardens have probably at some time or other left an earthenware or glass vessel containing water outdoors during a frosty winter's night. If so, I daresay on taking it up the next

morning you found it cracked. In New York a little time ago there was some talk of using glass-lined pipes, having between the glass and the metal a layer of plaster of Paris, which being a non-conductor of heat, would prevent the water freezing, and the water would run quite pure through the glass lining. The water flows into the cracks and crevices of rocks. In the winter time the water turns into ice, and with the ice comes increased bulk. This repeated year after year causes disintegration of the rocks. By this means many mighty fragments are detached from the original mass. Indeed, this increase of bulk consequent on the conversion of water into ice is one of the causes of landslips. That terrible landslip at Elm, in Switzerland, which occurred in September last, probably had its real, if not apparent, origin in this remarkable property of water. A large part of the village of Elm was then destroyed, and it is now threatened with further disasters on three sides. The danger is considered so imminent that watchers are always posted, day and night, to signal to the villagers when the mass—the rift between which and the mountain itself widens perceptibly each day—seems likely to slip entirely. Several landslips have occurred in India, which are, I believe, directly traceable to this cause. In the soil this expansion causes the breaking up of hard clods.

Water usually freezes at 0° C. and ice melts at the same temperature. In liquefying ice the temperature remains constant while there is the least bit of ice unmelted. This temperature has been taken as one of the fixed points of the Thermometer. The other fixed point taken is the temperature at which water boils or passes into gas, that is 100° C. or 212° F. under ordinary atmospheric pressure. Under diminished atmospheric pressure water can be cooled far below the ordinary freezing point without solidifying. If the atmospheric pressure be decreased the boiling point of water is lowered. In going up a mountain it falls 1° C. for every 327 metres ($1\frac{4}{5}$° F. for every 358 yards) of ascent, and this fact was once used for determining the heights of mountains. On the top of Mont Blanc water boils at $85\frac{2}{5}$° C. ($185\frac{4}{5}$° F.). In consequence of this constant lowering of the boiling point for every foot of ascent mountain climbers were unable, until quite lately, to cook their food on the top of very high mountains, as the water could not be made hot enough. A cooking apparatus has now been invented in which the boiling point is raised through increased pressure. The fact of the boiling point of water being raised through increased pressure has been taken advantage of in the extraction of gelatinous matter from bones. The bones are boiled in a strong vessel where the steam may be confined, and thus press upon the liquid. In boiling down the sugar cane just the reverse takes place. The sugar cane is boiled in a partial vacuum and by means of decreased pressure, a lower boiling point is obtained.

When a solid substance is dissolved in water the temperature generally falls. When cooks wish to make ices—of which people are often very fond, and I am afraid physiologists

would tell us, are very injurious to us—they surround their fruit or cream, or whatever they wish to freeze, by what is called a "freezing mixture." They mix together some pounded ice and salt, and get a mixture with a temperature considerably below freezing point. A freezing mixture of snow or ice broken small and salt should be in the proportion of about $\frac{1}{3}$ salt and $\frac{2}{3}$ ice or snow; then you get a mixture with a temperature of $-23°$ C. ($-9\frac{1}{2}°$ F.). If you should require a freezing mixture of even lower temperature than that, mix equal quantities of snow and Calcium Chloride, and your freezing mixture will have a temperature of $-45°$ C. ($-49°$ F.).

The next point on the syllabus is "Hard and Soft" waters. What is meant by *hard* water? Water is said to be hard when there is difficulty in making a lather with the soap, and the reason of this difficulty is that certain impurities in the water unite with the fatty acid of the soap to form an insoluble compound. Let us see what these impurities are, and the best way to get rid of them. One very common cause of hardness in water is Calcium bicarbonate or the acid Carbonate of Calcium, sometimes called Carbonate of lime, which is really only chalk held in solution by the presence of Carbonic Acid. Now the soap we use to wash with is composed of caustic soda and a fat acid, such as Stearic acid, and when soap is put into water containing Calcium salts it is decomposed, the Calcium uniting with the fat acid to form a Calcium or lime soap which is insoluble in water, and has no cleansing properties. There are several ways of getting rid of the hardness caused by Calcium Carbonate, as it is remediable it is called *temporary hardness.* What we do every day to soften hard water is to put a little soda into it. When a plate or dish or anything very dirty is washed you say that "you cannot get it clean without soda." Almost every kind of water contains some Calcium Carbonate, and this, by uniting with the fats, hinders the cleansing property of the water. The addition of a little soda prevents this. When soda—technically known as Sodium Carbonate—is put into water containing the acid Carbonate of Calcium, the Sodium changes place with the Calcium, and the ordinary Calcium Carbonate or chalk is precipitated. Lime water may be used instead of soda with the same effect. If we boil water containing this acid Carbonate of Calcium the Carbonic acid is expelled and the ordinary Calcium Carbonate is precipitated. This is what occasions the deposit or fur found in your kettles and boilers.

Another cause of hardness in water is Gypsum or Calcium Sulphate, and, as this cannot be removed by any other process than distillation, hardness due to it is *permanent.* Gypsum may be better known to some of you as alabaster; when it is boiled it loses the water combined with it, and is then known as plaster of Paris. Salts of Magnesium and salts of Iron also produce hardness in water. Of course, in all these hard waters a lather may at last be made by using a great deal more soap, but then look at the additional expense entailed by the constant using of so much soap

Hard water is not only bad for washing purposes, but it is also bad for cooking. Dr. Clark, of Aberdeen, invented a method for estimating the degrees of hardness of water, and from him we learn that the only way to make an infusion of tea as strong with waters of 8, 12 or 16 degrees of hardness, as you can with water of 4 degrees of hardness, is to materially increase in each case the quantity of tea. So that it is a matter of much moment to poor people to have tolerably soft water. Hard water increases their expenses in two very important directions—cooking and cleanliness. Some people add to the water Bi-carbonate of Sodium, but to anyone unused to it that spoils the flavor of the tea. Below 6 degrees of hardness water is termed soft, at 8 moderately hard, 12 very, and 16 degrees excessively hard. The waters of Loch Katrine, whence Glasgow is supplied, are beautifully soft and pure, having only about 1 degree of hardness and about 2 grains to the gallon of solid matter of all kinds. There are few waters purer than those of Loch Katrine, and in this respect Glasgow has the advantage of London and most other towns. The Thames and the New River have about 13 degrees of hardness. The river Trent is very hard; it contains a large quantity of Gypsum. The Aberdeenshire rivers, the Dee and the Don, run through a hard granite district, and, consequently, are very soft. By reason of the abundance of salts of Calcium and Magnesium in the sea, it is almost impossible to wash in it with common soap.

A few minutes ago I alluded to the fact of Gypsum giving off water when it was subjected to heat. Some of you, perhaps, have been thinking that you did not know it contained water at all. Many salts are combined with water, and it is to the quantity they hold in combination that the form of their crystals is due. This water is called the water of crystallisation. When this water is given off merely on the exposure of the salt to air, the salt crumbles to powder and is called *efflorescent.* Common soda is an efflorescent salt. If, on the contrary, a salt absorb moisture from the air, like the rock salt we had here the other evening, it is termed *deliquescent.*

Having spoken of those impurities in water which cause us discomfort and extra expense, we will now deal with those absolutely injurious to health. Not the most common impurity, but perhaps the most dangerous of all, is the presence of lead in water. If you had a lead cistern exposed to the air, and absolutely pure water running into it, and you drank of that water, in a very short time you would feel very ill. Fortunately, as far as this danger is concerned, absolutely pure water never does come into your cisterns, and tolerably pure water not very often. Pure water dissolves lead, and by drinking such water you would become seriously ill, and perhaps die, for lead is a cumulative poison, and its salts produce serious consequences even if taken in very small quantities for any length of time. Painters are particularly subject to lead poisoning, because of their constant use of lead paints; hence with them, lead poisoning has been called by a particular name "painter's colic." Ammoniacal salts in the water aid in dissolving the lead; other salts

instead of assisting rather retard the action. Hard water often dissolves the lead, forming with it an almost insoluble Lead Carbonate. This being practically insoluble is therefore harmless. Having regard to the poisonous action of lead on animal life, it is well, if possible, to avoid lead cisterns. Where you have them and would like to be quite sure that you are not taking poison into your system daily, go to your chemist and obtain three things. Buy a little Sulphuric acid, a few drops of Sulphuretted Hydrogen, and two or three pennyworth of Potassium Iodide. Take a clean glass—be careful that it is quite clean, because, in chemical testing, a very little thing will influence your results—and into the glass pour a little of the water out of your lead cistern, or drawn through your lead pipes. On to the water pour, as I do now, a little Sulphuric acid, and if there be lead in the water a heavy white precipitate, like this you now see, will be thrown down. (Ex.) As, however, you may sometimes get a heavy white precipitate by the action of Sulphuric acid on one or two other substances, take another glass and put in a little of the water to be tested as before. This time add to the water your Sulphuretted Hydrogen; if lead be present down will come a black precipitate like this. (Ex.) If you have obtained these two precipitates you may feel tolerably certain that the water is unfit for drinking purposes; if, however, you wish to be absolutely sure, beyond the possibility of being mistaken, add to the water a few drops of a solution of Potassium Iodide. The lead in the water will act upon the Potassium Iodide and form a singularly bright yellow precipitate. (Ex.) The color is so remarkable that it has had a special name given to it, and is known as King's Yellow. If you get these three precipitates with the three re-agents as we have to-night, the sooner you leave off drinking the water out of your lead cistern the better. Lead pipes are not so dangerous as lead cisterns, because light seems almost essential to the oxidising and solvent action of pure water upon lead; therefore, if your cistern be in a dark place it will be less harmful than if exposed to the full daylight. Lead pipes, however, are not altogether without danger, for some experiments made in New York showed that some water which had remained all night in lead pipes contained over one grain of lead in a gallon. The presence of vegetable matter seems to assist the action. If leaves drop into a lead cistern, the spots where they lie become quite corroded. If the lead be dull in appearance water does not seem to affect it so much as if it be in a bright and polished condition.

Now we come to a more general form of impurity in water, viz., organic impurities. Anyone of us is liable to find organic matter in our drinking water, and as this form of impurity is most injurious to the general health, it behoves us to have some simple means of testing suspected water, and of getting rid of the impurities before we drink it. I have no wish to produce a scare, but I would like to lay just one or two facts before you, so that you may understand what a fruitful source of disease impure water is. In the years following the outbreak of cholera in 1853 inquiries were made into the causes of the spread of this terrible disease with the

following results. During the earlier epidemic of 1849 two rival water companies supplied a district in the south of London with water, one company supplying about 25,000 houses and the other nearly 40,000. The houses ran side by side in all respects alike save for the difference of their water supply. Both companies drew their water from pretty nearly the same source, low down the river, where it was much contaminated with town sewage. In one case the death-rate was 125 per 10,000, and in the other 118. In 1853 there was another outbreak of cholera, and the houses which four years before had had the awful death-rate of 125 per 10,000 had now a mortality of 37. Those houses which in 1849 had a mortality of 118 now had one of 130, so the outbreak could not have been less alarming. During the interval between the two outbreaks one of the water companies had gone higher up the river where the water was comparatively pure for its water supply. The effect of this was an enormously diminished death-rate amongst the inhabitants of the houses supplied by it. This is by no means the only instance I could find you of the spread of cholera in the years 1849 and 1853 through drinking impure water. Typhoid fever often solely arises from drinking bad water or inhaling foul sewer gases. Scarlet fever is also sometimes traceable to the same source.

Now to consider three or four ways of detecting the presence of organic impurities in water, and then let us think of the best means of getting rid of them. In either case we shall only consider easy and inexpensive means within the reach of everyone.

First get from your chemist a little Lead Acetate and a little distilled water. Dissolve the Lead Acetate in the water, and then take a small piece of white blotting paper and lay in it to soak. Take about a wine glass-full of the suspected water and boil some of it away. Then, as it boils, hold your piece of paper soaked with Lead Acetate over the steam arising from it just as I am holding a piece over this boiling water now. (Ex.) If the water contain organic matter the paper will probably turn black just as you see this has done. Organic matter mostly produces Sulphuretted Hydrogen. On heating water containing it the gas is given off, and, coming into contact with the paper soaked in Lead Acetate, blackens it. Wells or springs in the neighborhood of graveyards are, as you may guess, generally well supplied with organic impurities, and in connexion with such waters you may sometimes hear "nitrates" freely talked about. Where you meet with nitrates in water you may feel tolerably sure that that water has passed through soil containing decomposing animal matter. How are you to tell whether the water contains nitrates? Concentrate the strength of the impurity by boiling down a little water to one-half or one-third its original quantity; put into it a small piece of clean Copper, and then add a few drops of Sulphuric Acid. If there be a nitrate present a reddish brown, unpleasantly smelling gas will be evolved. (Ex.)

A simple method of testing water for organic impurities has been

given by Professor Roscoe. I have two tubes, one containing pure water and the other water which, although it looks fit to drink, I know to be very impure. Into the pure water I drop one drop of Potassium Permanganate—which I have already recommended to you as a disinfectant on account of its cheapness and its great oxidising powers; the water is colored pink; two drops, the color deepens; three drops and we have a bright magenta. I shake up the water, I boil it but the color remains. Into the impure water I drop one drop of Potassium Permanganate, the water is not colored; two drops, a slight coloration, but it is transient, for on shaking it up that too disappears. I now add several drops, and now, indeed, we get a deep color, although not magenta, like we had with the pure water, and on boiling even this goes also. Sometimes the color does not come out on boiling but it is altogether a different color from the clear bright magenta. The reason why there is this difficulty in permanently coloring impure water with Potassium Permanganate is that it contains oxidisable matter, and the Permanganate has its work to do in oxidising these impure particles before it can color the water.

An exceedingly simple test was given for good drinking water, some years ago, in the *Pharmaceutical Journal*, which would not even cost you the few pence involved in the previous tests. You have merely to put half a pint of the suspected water into a clean colorless glass-stopped bottle, drop in a few grains of the best white sugar and let the bottle stand in the window of a warm room. If, after about ten days, the water remain clear, it is good; if it become turbid it is open to suspicion of sewage contamination.

Now it only remains to us to consider how to make bad water fit for drinking. Unfortunately the means at our disposal to effect this are not very numerous. If absolutely pure water is necessary to you, distillation is the only method you can employ to obtain it, and that process has already been described to you. If you are content to have water free from organic or harmful impurities, all that is necessary for our ordinary requirements—you may obtain it by filtration, unless indeed the water is very bad. There are several kinds of filters: some made of sand, some of pounded glass, some of sand and charcoal, some of charcoal only. If you only wish to get rid of gross impurities, solid particles, often visible to the naked eye—if you pass the water through clean sand it is sufficient. But if you wish to purify the water of organic impurities you must use charcoal. If possible let the grosser impurities in the water be arrested by a sponge, and then let the water trickle out of the sponge on to layers of charcoal or charcoal and sand. The atmospheric Oxygen contained in the charcoal oxidises organic matter coming into contact with it, and the water in its passage through the charcoal not only has its organic and soluble coloring matters removed, but also undergoes aeration. Charcoal retains this property a long while, and even when it is exhausted may easily be renewed.

After what I have just said as to the evil effects of impure drinking

water, it is only right that I should reassure you as to the quality of the water supplied by the seven companies which now serve London with water. I have here a Report for the month of September to the President of the Local Government Board of the results of the daily examination of samples of water provided by the different companies. Those who have the happiness to be supplied by the New River Company will be glad to know that of the twenty-six samples analysed during September, all, without exception, were reported "well filtered, clear and bright." Of the twenty-six samples each of water supplied by the Chelsea, Lambeth, West Middlesex and Southwark and Vauxhall Companies, only one in each case was reported "very slightly turbid," all the others were clear and bright, The Grand Junction Company had two samples "very slightly turbid," and the East London Company six, but in both cases the remaining samples were equal to those supplied by the other companies. The Report sums up that altogether the water supplied by the companies during September was of "excellent quality." The water supplied by the Lambeth Company was the hardest, and that supplied by the West Middlesex Company the softest.

On page 4 of my first lecture on Water there is a misprint, which renders the paragraph in which it occurs somewhat confused. Instead of the deep water of the Mediterranean containing 5 per cent. of Nitrogen it should be 35 per cent.

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LECTURE I.

I HAVE chosen a literary subject as distinct from a purely scientific of purpose. We have no desire in the studies we may carry on in this hall to restrict ourselves wholly to any one special branch of knowledge. The healthiest mind seems to be that which deals with many aspects of known things and is not narrowed down within the limits of any one particular study. And, further, a course of lectures on a subject wholly literary may with advantage be thus interpolated amidst lectures on natural science if only as our protest against the fanciful idea that there is a species of divorce between the literary mind and science and between the scientific mind and literature. The highest men and women blend both natural science and the study of books in their work, and though we may not hope to reach their level we can in this matter as in others follow in their wake.

It is the fashion to praise our Shakspere. Everyone belauds him. But not everyone reads him and very far from everyone understands him. The praise is often unthinking and indiscriminate. My desire in these lectures is to look with you a little more closely into his writings and to try to get near the heart of them. As fellow-students we may read him and reflect upon him, pausing to ask why he has used this particular word or that special phrase, what he would have us understand by this turn of thought, what he desires to convey in that noticeable passage. I do not think we may hope to comprehend him in full. But much of the excellence in him we shall be able to understand, in like fashion as the physical beauty of a woman's face and form can be seen and wondered at by mankind in general. The fullest, deepest significance of her beauty and all the thought that lies behind her eyes are not for all men. And so with our Shakspere the innermost thought of him is only comprehended by those rarer minds, to whose fuller comprehension of his words and works haply some of us here may in good time attain.

I shall speak first of his dramas as a whole, then of certain errors, as they seem to me, of which he is guilty. The requisites for the dramatic writer will be studied and the central ideas that run through the majority of his plays pointed out. His wealth of thought and word and imagery will conduct us to a study of his chief characters, and we shall end with a glance at his last play, "The Tempest."

A. The Dramas. The customary division of plays into tragedies, comedies and farces may be taken as a guide. (1) The *tragedy* has for its essential element pathos. Death is not absolutely necessary in tragedy. Pathos is necessary, and as the greatest of human suffering results from death, this latter plays an important part in all tragedies. Using pathos in its broadest significance as human suffering, involving human struggles and human passions, I am inclined to regard "The Merchant of Venice" as to the full as much a tragedy as it is a comedy. But no death occurs in that play. (2) The *comedy* has for its essential, wit. The remarkable bringing together of things that apparently are wide as the poles asunder and yet have an analogy the more striking as it is the more unexpected, this that we name Wit, moving us to smiles rather than to laughter, runs light and airy through the comedy. (2) The *farce* includes to me all that large class of plays where the fun is of a nature less refined and more broad. Our English farces, the French Palais Royal productions, burlesques, pantomimes are examples. The essential in these is humor. We laugh rather than smile at such plays as these.

Now, in dealing with the Shaksperean plays, it is usual to classify them as those of his early time, of the middle period of his work and of his later time. The earliest bear the stamp of youth. They may be roughly called farces as they depend largely on humor. But mixed with the humor is so much of the lyrical and fantastic element that they stand quite alone among dramas, bearing a distinctive stamp. The "Comedy of Errors" and the "Merry Wives of Windsor" are examples. The plays of the middle period might be named comedies in a large view of them. Truly the historic plays come within the limits of this middle time. But with them is mixed so much of the true comedy element, there is so much play of wit and fancy, that it is little straining of words to name the historic plays *in many cases* comedies. "Henry IV." will illustrate my

meaning, whilst for unquestioned comedy of this middle time "Much Ado about Nothing" will serve as example. Finally the tremendous tragedies, such as Hamlet and Macbeth, are the product of his later years.

But while this somewhat artificial division of the Shaksperean plays holds good in part, it is of vital importance to bear in mind that each of his plays is at once tragedy, comedy, and farce. One or the other element may predominate, but in every drama a happy blending of all three obtains. Thus even in "Hamlet," so notably tragic, there is wit and to spare in some of the words of the Prince himself, and in the homely talk at the grave-side of Ophelia there is no lack of humor. And this same blending of the three great elements of pathos, wit, and humor is to be expected from the master. For he deals with and portrays human life as it actually is, and in human life these three are inextricably interwoven. They glide the one into the other. Our tears and laughter have founts that lie close adjacent. We laugh until we cry, and we cry until we laugh. And therefore in the fact that every play of William Shakspere is at once tragic, comic, and humorous we have proof that he sees life as it is with its comingled tragedy, comedy, and farce.

B. Errors. There are spots on the sun and faults in Shakspere. But as the spots on the sun affect very largely the conditions of our world and cause very considerable perturbations on "this dim spot called earth" so the errors of Shakspere have their importance, and must be studied by the earnest student. These errors seem to me to fall under three heads: the use of rhyme instead of blank verse, errors due to carelessness, and the frequency of anticlimax. (1.) The use of *rhyme.* Until the time of Christopher Marlowe, English plays, even the tragedies, had been written in rhymed verse, a vehicle that does not seem the one best fitted for the conveyance of powerful ideas or the expression of deep emotion. Kit Marlowe, so little read to-day, unfortunately for to-day, was the first and for a long time the only man who stemmed the tide of popular versification, and wrote tragedies in blank-verse. To him we owe the change that comes over the letter of those dreams of Shakspere that we call dramas. The earlier plays are very full of rhymed couplets. But as he grows in intellectual wisdom and stature we find the rhymed lines grow less and less in number, and in the latest plays the influence

of Marlowe has become so strong that very rarely is the stately blank-verse broken in upon by the jingle of rhyme. I venture to use the word "error" whenever a strong scene that has run its length in blank-verse is concluded by two or more lines of rhyme. I am aware that many urge that these rhymed endings "take the actor off" in effective fashion. Even with this idea I join issue, as in every case I seem to see a lowering of the dignity of the play, by this introduction of a metre other than the lofty blank-verse. But in many cases these rhymed couplets terminate an act, on the termination of which the curtain would fall and no need occurs for "taking the actor off." As an example of these weak endings, I take King Richard II., act i., scene 2, where the exit of the Duchess of York is spoiled by six final rhyming lines, the last two of which are:

"Desolate, desolate will I hence and die.
The last leave of thee takes my weeping eye."

(2.) *Carelessess.* Shakspere undoubtedly does not always exercise that scrupulous care that the exacting nature of modern criticism requires at the hands of authors. In his versification he is often careless. By no manner of means is he one of those whom Dr. Johnson names the "Correct Poets." Lines often halt and lines are often incomplete, and in matters of fact a like want of care is evident. Thus in the "Winter's Tale," the third scene in the fourth act is laid in Bohemia, a desert country near the sea. It is hardly necessary to say that Bohemia is at no point near the sea. And in "As you like it" Orlando sees in the forest of Arden in temperate Belgium a denizen of tropical regions, a lioness.

(3.) *Anti-climax.* When a noble poem or a strong scene terminates in such a fashion that there is an evident lowering of the high tone that has prevailed, and there is a failure to satisfy certain expectations that have been raised, we have an instance of anticlimax. Tennyson's "Enoch Arden" is a case in point. The poem is a noble work of art. Its last lines (but three) are full of a notable strength and pathos. But the last three lines are a terrible anti-climax. Enoch has at the voice of the storm wakened for the last time, has risen and stretching forth his tired arms, cried aloud,

"A sail, a sail! I'm saved!
And so fell back and spoke no more."

This is the true climax of the poem. But alas! Mr. Tennyson adds the three unhappy lines:

> "So passed the strong heroic soul away,
> And when they buried him the little port
> Had never seen a costlier funeral."

The dramas we are now studying abound in anti-climax. Scarcely a play of Shakspere ends as our modern taste, at least, requires dramas to end. Almost all of them terminate weakly. To take two examples. The play of Hamlet actually ends with the introduction of Fortinbras who has never once appeared upon the scene in the earlier part of the play. As acted to-day, Hamlet's death on the line, "The rest is silence," closes the wonderful drama, and even Horatio's speech after, and far more all the unfortunate business in regard to the Norwegian prince, are of the nature of anti-climax. My other illustration is from the "Merchant of Venice." I venture to think that the whole of the last act is in some sense anti-climactic. Somehow we want the curtain to come down for the last time on the forlorn figure of Shylock, passing out from the court into the streets, whilst the jeers and execrations of the Venetian mob ring in our ears. But if the dreamy last act is essential, as on the method of construction of this play adopted by its author, it *is* essential, even then the ending would more fitly come some lines before the termination of the play as we have it now. Might not the play end at the tenderly suggestive line that breaks from Portia's lips and falls upon the ears of six young lovers and a solitary man named Antonio? I mean the line, "It is almost morning." The coarse jesting of Gratiano is sadly out of place, though there is consistency in giving to the talkative one the last word of the play.

C. Requisites for a Dramatist. Some of these are the ordinary requirements for the general writer, certain of them needing, if I may say so, intensification in the dramatist; and some are very specially requisite for him. (1.) *Observation.* That Shakspere was a great observer of human nature has passed into a copy-book phrase. So evident is this throughout that it is difficult to quote a special case. But reference may be made to a scene in "Julius Cæsar" (Act iv., scene 1), wherein after the second triumvirate, Octavius, Antonius, Lepidus, have divided the Roman world between them, the last-named passing out, the two that are left at once fall to fault-finding in respect to him. No man over the age of

twenty ever quitted a room where two or three of his friends were gathered together without the certainty that his personal character would be the next topic of discussion, and that its reputation would probably suffer.

(2.) *Command of words.* It is late in the day to credit Shakspere with this gift. I would only quote two passages. One is to show his remarkable power of heaping up words and phrases as descriptive of some special thing or idea, in such richness and profusion that they seem eternally exhaustive of the subject. Macbeth is speaking of that sleep which he has murdered.

> "Sleep that knits up the ravell'd sleeve of care,
> The death of each day's life, sore labor's bath,
> Balm of hurt minds, great Nature's second course,
> Chief nourisher in life's feast."

The other is taken as an illustration of his able use of words in mere description, as, in fact, to some extent an instance of mimetic writing in which the sound of the words expresses the sense. Cordelia, bemoaning the sorrowful agonies of her father, Lear, in the storm of the past night, speaks of his exposure to the lightning. The adjectives and the noun utilised in describing that lightning show that which I mean.

> "To stand . . . in the most terrible and nimble stroke,
> Of quick cross lightning."

(3.) *Submergence of himself* in his characters. This, more than all others, is essential to the dramatic writer, and this is the possession of Shakspere to a greater extent than of any other. He never speaks. His characters speak. The character of William Shakspere never once obtrudes itself. Indeed we have no evidence at all as to the personality of our dramatist. The man William Shakspere is almost entirely unknown to us. We are not sure as to his religion, or as to his politics. He is lost in the men and women he has created. He is as a source of light, invisible because of the very splendor of the rays itself has given forth.

(4.) *Pathos.* The power of stirring men deeply and moving them to tears is necessary to the playwright. It will be noticed that pathetic *scenes* in Shakspere are not numerous. It is rather by slight touches often isolated that he produces his greatest effects. And herein he is again most true to nature, where scenes of any duration dealing with some

specific emotion are rare, but where the sudden rush of tears to the eyes at some phrase, some sound, some odor, some old memory is frequent enough. In Julius Cæsar, act v., scene 3, Brutus beholds the dead body of his friend Cassius. An inferior writer would have given us a long pathetic speech. The first of dramatists represents the old Roman as saying, "Friends, I owe this man more tears than you shall see me pay." Read this with a pause after the word "tears," and consider the dignity and sadness of it all. As another case, take the line of Macbeth when he comes out from Duncan, slain by him an hour before, and speaks to Lenox on the sad morn.

> "Had I but died an hour before this chance
> I had lived a blessed time."

Finally, as a rare example of a scene full of pathos, that between Lear and Cordelia, in act iv., scene 7, may be taken. Even in this, the finest parts seem to me to be in certain little touches, missed perhaps by many.

The physician begs Cordelia be near the king when they wake him. "I doubt not of his temperance." The storm of the last night is wholly passed. The old man will be tired and gentle from very weariness now. All outbursts of passion are at an end. To the very finish of the play, in truth, no more of the terrific lines laden with anguish occur that are so frequent in the earlier scenes. A very broken down old man. But note her answer to the physician's request. "Very well." Not "I will be by him." The answer is mechanical. She assents, but in the words and tone of her assent, I think we read her remembrance of the last time when his waking eyes met hers. His were angry, and the light of his coming madness looked out on her. He may be thus again to-day.

"Had you not been their father these white flakes had challenged pity of them." The poor white hair runs through her slender fingers and at the words—

> "Was this a face
> To be exposed against the warring winds?"

Her soft, smooth cheek rests against his worn face. "Poor perdu!" she calls him, for she has lived in France since the last parting, and the delicate name comes aptly to her lips. As she begins to wake, the old fear returns. She half shrinks from him. "He wakes," she says. "Speak to him." And when taking heart of grace she speaks, the name she

uses is not "father," but "my royal lord," "your majesty." Herein is the exercise, doubtless, of a wise discretion. To him thus coming to life again the names by which he is most frequently addressed will bring the least shock. But there is also, I believe, something of dread as to his reception of her in the naming him "lord and majesty" rather than "father." As he slowly recovers the pathetic cry breaks from him "Fair daylight!" Daylight is falling upon the eyes that have grown weary with the sight of storms and such strange phantasms as sane men know not. The sadness of that cry deepens as we remember how brief a while the sunlight, made by the presence of Cordelia, will last. "I will not swear these are my hands." The light shines through their thinness as they quiver in the air. And when the daughter sobs—

> "O look upon me, Sir,
> And hold your hands in benediction o'er me."

What is the significance of that wonderful next line?—

> "No, Sir, you must not kneel!"

Why is the first word in that line an almost inarticulate shriek? Because the old king and father would cast himself to the ground at her feet; he is so broken down. And for pathos, very sublime in its simplicity, let us read quietly to ourselves these phrases—

> "To deal plainly
> I fear I am not in my perfect mind."
> . . . "If you have poison for me, I'll drink it."

And the line with which, leaning upon Cordelia, he passes out—

> "You must bear with me:
> Pray, now, forget and forgive: I am old and foolish."

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LECTURE II.

III. Requisites for a Dramatist (continued). (5) *Wit.* Wit is the seeing of analogies. It is the power of noticing likenesses where the ordinary person sees none. Things, phrases, ideas apparently wholly unconnected are by the witty person brought into sudden juxtaposition, their resemblance recognised before this by him is now observed by many, and not a few are inclined to say "Oh, I was just going to say that myself." Butler was author of "Hudibras," the satire on the Puritans. Charles II. admired the humorous book so greatly that he was rarely without a copy of it by him, even, so say the chroniclers, when he went to bed. No student of history will, therefore, be surprised to learn that Butler starved to death in the reign of Charles.

After his death, in our admirable English fashion, we erected a statue to Samuel Butler. John Wesley, years later, seeing the statue and remembering the story, hit off the following couplet:—

> "The poet's fate is here in emblem shown,
> He asked for bread and he received a stone."

He sees the resemblance between the treatment of Butler and a verse in the New Testament: he brings the two together and the world says "How witty!"

Shakspere has command of wit. Of the two mirth-movers, this and humor, I am inclined to think he possesses more of the latter. But assuredly there is no dearth of the former. The scene between Jaques the cynic, and Orlando the brave, open-eyed, unwarped man in the second scene of the third act of "As you like it" furnishes example. As light banter between these two contrasted beings it is almost as excellent as any of the scenes between Beatrice and Benedick in "Much ado about Nothing," though it necessarily lacks the love interest of these. As instances of ordinary wit I may quote—

"*Jaq.*—You are full of pretty answers. Have you not been acquainted with goldsmith's wives and conned them out of rings?

"*Orl.*—Not so. But I answer you right painted cloth from whence you take your questions."

To those who remember the old custom of having posies or mottoes engraved in rings and aphorisms of more or less copy-book order woven on tapestry, the badinage here will be very comprehensible. Or again as instance of a rougher kind of wit—

"*Jaq.*—By my faith, I was looking for a fool in the forest and I saw—you.

"*Orl.*—He is drowned in the brook. Look but in and you shall see him."

For a finer case, consider the phrase of Jaques when the quick wit of Orlando forces from him a half-unwilling acknowledgment.

"You have a nimble wit. I think it was made of Atalanta's heels."

And finally a quotation in which the wit is at its most delicate, one wherein blends a most rare accompaniment of wit, pathos. When Jaques in jesting fashion asks what stature Rosalind is of, the answer of Orlando is—

"Just as high as my heart."

6. *Humor.*—This moves us to laughter. It is altogether broader, less refined than its fellow. Wit may be, and, I think, generally is, the result of education. Whilst humor may be improved and ripened without doubt as time goes on, much of it seems to be inherited. Wit depends mainly on verbal play, but humor depends on facial expression, on gesture, on pose of the body, on that which has been called "the flavor of character." Pathos goes often hand in hand with this, and the greatest masters of the one have usually been masters of the other. But in this connexion I am concerned rather with that form of humor alone which is mirth-stirring. And in this the plays of Shakspere abound. At the mere mention of the word a score of names leap to our lips. Speed, Launce, Lancelot, Autolycus, Falstaff, Dogberry, Bottom, the Grave-digger, are only a portion of them. Sometimes the humor of the plays depends on mere practical joking, but this is rare. It seems that the laughter to which we are stirred is due in the main to three causes. These are (*a*), confusion as to words, (*b*) odd reversals of the meanings attached to certain words and phrases, (*c*) an entire misconception of the person's position and his relation to all his surroundings. Let us take as illustration of these,

Act iv., Scene 2, of "Much Ado about Nothing." It is the scene between Dogberry and Verges, those antetypes of our bench of Middlesex magistrates, the watch and the two arrested men, Conrad and Borachio. Humor meets us all aglee on the threshold of the scene. This strange pair, doubtful as to their own power to conduct even the simple preliminary examination of the prisoners have enlisted in their service, of all men in the world, "the Sexton." Here then is an instance of the third form of humor, (*c*) given above. All through the scene we have this form rife. Take as another illustration the manner in which Dogberry addresses the two prisoners. To the first, Borachio, he is all ear-embracing smiles, and his words are "What is your name, friend?" Instantly he is doubtful as to whether he has chosen the best method of address. Therefore, in speaking to Conrad, he flies to the opposite extreme, and with knitted brow and lips protuberant jerks out, "Yours, sirrah?" Examples of the word-confusion abound. The first line in the scene reads, "Is our whole dissembly appeared?" Later on, Dogberry would have the men "opinioned," and he is all anxiety to know if they do not "suspect his years and office." In these confusions, known to us now-a-days as Malapropisms, Shakspere though precedent to Sheridan is certainly surpassed by that writer in ingenuity. Nothing to equal the delightful blunders of Mrs. Malaprop in "The Rivals" has yet been forthcoming in English literature. But in the third form of humor marked (*b*) above, I think the great dramatist is unrivalled. The curious, and in many cases daring, misconception of an idea of which he makes his characters capable, is a striking peculiarity of his. "Which be the malefactors?" asks the Sexton. "Marry, that am I and my partner," blusters Dogberry; and as greatest of threats to the men in custody he tells them they shall "be condemned into everlasting redemption for this."

7. *Power.*—When I turn to the consideration of this quality in the writings of our Shakspere, a doubt comes upon me that in the language I am compelled to use I may be accused of exaggeration. The phrases forced upon me when I consider the strength of thought and language in certain passages may, I fear, appear to have something of hyperbole. But I am bound to say that there are lines in Shakspere that are to me stupendous and terrific. I am not acquainted with any other writer who so entirely stuns and *staggers* me as this man does at times. The effect is

usually produced by very simple words, but the idea involved in these is of such intense power that one pauses on it half-dazed and breathless. In "Antony and Cleopatra," at the end of the 11th scene of act iii., occurs a case in point. It is necessary to bear in mind that in the forthcoming battle Antony will be slain. This is the last interview between him and Egypt save that fatal one on the day of Alexandria.

> "The next time I do fight
> I'll make death love me; for I will contend
> Even with his pestilent scythe."

"Pestilent scythe" is a tremendous phrase. But the strength of the whole passage deepens as we remember that the next time he fights he will be wounded to the death. He will make death love him—even unto death. He "will contend with his pestilent scythe." Strange double meaning! Not alone will he fight as armed with Death's weapon. He will fight against Death himself and come off conquered.

In "Macbeth," act ii., scene 2, occurs more than one instance of this intensity of Shakspere. Most notable are the lines near the end of the scene:

> "Will all great Neptune's ocean wash this blood
> Clean from my hand! No; this my hand will rather
> The multitudinous seas incarnardine,
> Making the green-one red."

The image is appalling. My hand cannot be cleansed by the waters of wide ocean. It will the rather stain all the seas that belt the globe to its own hue-blood-red.

In the storm-scene of "King Lear," act iii., scene 2, the scene commencing "Blow winds and crack your cheeks! rage! blow!" there is passage on passage of the kind to which I now make reference. Of these one always strikes me as perhaps the strongest idea in all the plays. The king cries aloud to the thunder

> "Strike flat the thick rotundity of the world!"

The huge round globe to be smitten down into one vast level plain! Or again in the same play and in the scene to which your attention was called in my last lecture, act iv., scene 7, the scene between the king awakening and his daughter Cordelia, have we not one phrase of intense power interpolated in the midst of the intense pathos?

> "You do me wrong, to take me out o' the grave;
> *Thou art a* soul in bliss; but I am bound

> Upon a wheel of fire, that mine own tears
> Do scald like molten lead."

If I read this passage aright its significance is this. I am bound upon a wheel that is of fire; but my tears are of such burning agony that they falling on this wheel scald it as molten lead would scald a colder thing. These my tears are as much hotter than this the wheel of fire to which I am bound as it is hotter than things ordinary.

8. *Passion.*—I use the word here in its limited sense, as applicable to love. The power to portray the warmth that "life's ascending sun" stirs at the heart of youth and maiden and that glows with a deeper if calmer strength in the bosoms of men and women is possessed by him. The want of this same power is one thing that must, I think, for ever render the poetry of Milton not to be compared with that of Shakspere. Milton's poems are devoid of passion. A sublime austerity reigns throughout them. But none that has read "Romeo and Juliet" or "Antony and Cleopatra" will deny the power of their author to deal with that passionate side of human nature that is turned towards the opposite sex. Let us take one fragmentary scene from the former play. It is the end of scene 2, act ii., that which is usually known as the Balcony scene. They have parted: have bidden one another a thousand times "Good-night." But even as he slowly withdraws she is back at the window once again whispering his name. To the end of the scene their low talk in the half light of an Italian night drawing towards morning amid the odors of an Italian garden and to the faint, uncertain music of half-awakened birds is redolent of passion. "Romeo!" she calls him. His name for her, "My Sweet!" She has "forgot why she did call him back again." He would stay there "till she remember it." Two phrases at the end of the scene, one from the lips of each lover, are fullest of passionate significance. He would be the bird of which she speaks, at once her joy and her prisoner. "I would I were thy bird," he says.

> "Sweet, so would I.
> Yet *I should kill thee with much cherishing.*"

In that last line speaks out the warmth and passion of the Southern woman's nature.

And in his wish as she quits him—

> "Sleep dwell upon thine eyes, peace in thy breast!
> Would I were sleep and peace so sweet to rest!"

we have the heart-sick longing of love made audible in words.

9. *Situation.*—In addition to a command of the various emotions named above, the dramatist requires in his craft the art of constructing and of leading up to what is technically called a "situation." This is the climax of a play or of some part of a play, in which many things gather themselves together and emotions of great complexity are stirred. Our modern dramatists, with wisdom, arrange these startling effects so that they occur at the end of plays or scenes. Shakspere, on the other hand, often locates them in less telling positions than these. An instance of marvellous ability in the construction of a skilful situation, and of equal ability in preparing events before it in such a fashion that they naturally conduct to the catastrophe and intensify its strength, is the familiar one of the climax of the play scene in "Hamlet." He who will analyse the mental position of each man and woman who witnesses the play within a play, of the murder-laden usurper of the throne, of the weak, uncertain wife who has never allowed herself to look too curiously into the events of the last few months, of Polonius with his shrewd, worldly wisdom that has partly guessed ere this, of Horatio watching at the word of Hamlet the workings of the King's face, of Ophelia with her lost love of purpose saying in undertone to her things half jest, half earnest, but wholly painful, of the many courtiers among whom we may be assured there have been elbow-nudgings and whisperings and the knowing smile that is half sneer when the death of the old and the marriage of the new King have been the subject of gossip, of Hamlet rightful King as well as "son of a dear father murdered"—he who will realise, however faintly, what varied emotions, all culminating on the one event, are gathered together in the great hall at Elsinore, can understand the force of the situation when, crawling across its floor, moves Hamlet, nearing the King every second, hissing out the words: "He poisons him in the garden for his estate. His name's Gonzago: the story is extant, and written in very choice Italian. You shall see anon how the murderer gets the love of Gonzago's wife;" on which, in a moment, the hall, with a tumult of cries, empties, King, Queen, Courtiers vanish, and on the empty throne that is rightly his Hamlet flings himself.

V. The Wealth of Shakspere. He has a wealth of

language and a wealth of thought of the very rarest. (1) On his richness in the matter of *words* I have already touched. But I am inclined to take one other illustration to show his power in this respect. I take it from "Twelfth Night." In act ii., scene 4, the Duke, who loves Olivia, has held light, graceful talk with the page Cesario, who is in truth Viola, that loves the Duke. He calls for an old-fashioned song, and to my thinking the words in which the song is pictured by him are a remarkable instance of the rare skill with which our writer uses phrases. They have a quaint, old-fashioned ring about them that is very musical and dreamy, and carries us back to days that were even in the Shakspearean age, old times.

> "O fellow, come, the song we had last night,
> Mark it Cesario; it is old and plain.
> The spinsters and the knitters in the sun,
> And the free maids that weave their threads with bones
> Do use to chant it; it is silly sooth,
> And dallies with the innocence of love.
> Like the old age."

(2) *Wealth of Thought.* It is late in the day to remind ourselves that out of the mouths of the men and women of Shakspere's plays have come to us some of our noblest teachings and most deep-sounding reflexions. When the character is a Hamlet, or a Jaques, or a Brutus, an Imogen or a Portia, philosophy most human is our guest to comfort and instruct. The most intricate riddles of life are partially unravelled by these, the springs of its most sacred emotions are laid bare, the problems and speculations of all ages and of all climes are discussed, light falls upon the dark places, and we weaker ones find strength and guidance in the words of our nobler brethren and sweeter, purer sisters. The speculations of Hamlet on life and death, the half-dreamy analysis of Elizabethan life by Jaques in "All the world's a stage," the meditations of Portia, half to herself, half to her other self Bassanio, as she gives herself to him, or her dignified appeal for mercy to the man to whom none has ever been shown, these, and passages such as these, crowd in upon our mind when we think of the suggestions, the injunctions, the encouragements, the comfortings, the aids we have had from these beings whom he has made to live for us.

(3) *The complexity of thought.* I desire here to bring out an idea with regard to the writings of Shakspere that is in

some sense distinct from the last. His thought is confessedly deep. But it is also complex in another sense. Phrases uttered by his characters have so manifold a meaning. To the speaker they may convey one idea; to his auditor on the stage another; to his auditors in the theatre or the study yet another. As example, notice one line of Polonius in his dialogue with Hamlet, act ii., scene 2. He is surveying with the critical eye of a court Chamberlain the young Prince. "He is gone, far gone; and truly in my youth I suffered much extremity for love; very near this." As if Polonius in any one of his emotions, least of all in that of love, could feel as Hamlet! The two are not in the same hemisphere of suffering. The sensitiveness of Polonius is and always has been, a negative quantity. But Hamlet is of that keen, intellectual nature that feels joy and pain in a manner unknown to lesser men.

Or, as last quotation, take the pretty threefold meaning to her, to the Duke, to us who are in her delicious confidence, of one answer of Viola, in act ii., scene 4, of "Twelfth Night." She is page to the Duke in seeming; she is his woman-love in her heart. Favor has the two meanings, "grace or permission" and "countenance." As he uses it the word has the latter significance: as she employs it the word has both its meanings. He tells the boy that already ere this, young as he is, his eye must have "rested on some favor that it loves." "Hath it not boy?" The answer is—

"A little by your favor."

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LECTURE III.

VI. His Characters.—In an hour's lecture I have no hope to do more than make one or two suggestions as to some of the most prominent characters in the dramas of Shakspere.

> "Age cannot wither 'these' nor custom stale
> Their infinite variety."

A word as to the method adopted in criticising the men and women of the plays. The play is carefully read, and every reference to the particular character under study made by others of the persons of the drama noted. All his or her own utterances that give any insight into the nature of the person are in like manner recorded. Inferences are drawn from these as to the character of the individual. That is, I do not simply, after reading through the play once or many times, think, as it were, *ab extra*, on each character. I try to build up the personality of each out of the phrases used by each or of each.

Let us consider (1) Some of the women (2) Some of the men. (1) *Women.* Here a curious and painful reflexion meets us at the outset. Shakspere never saw any of his women characters played by women. Consider all that means. The creator of Portia, Desdemona, Miranda never saw a woman play one of these parts, never saw his creation at its best. For in the Elizabethan time all female parts were played by boys. When we reflect that the voice requirements made it necessary that these boys should be of such age that their tones were still treble, and when we reflect on the general characteristics of boys at that age we can form some faint conception of the "falling off" that must have been. Imagine Portia enacted by a hobbledehoy! The poor youth could not be expected to rise in any sense to the womanly height of her sweet mind. A grown man can hardly hope to understand such a woman as this in full measure. But a boy! And this system must have

reacted on the men players also. No Romeo could make real love to a Juliet of the same sex. Lear's agony over the dead Cordelia must have lost much of its force and terror. That Shakspere never saw one of his women characters actually realised as we to-day most happily behold them is to me a very pathetic consideration. It calls to mind the fact that Beethoven, the Shakspere of music, in his later years fell deaf. Hence the actual hearing of all his latest and finest compositions was denied him. It calls to mind the fact that Homer was blind and never beheld the faces of his auditors kindle and glow with enthusiasm as he in his darkness recited the Iliad at the games of Greece. Homer blind, Beethoven deaf, Shakspere doomed never to see a woman act in his plays. Strange irony of fate!

(*a*) Lady Macbeth. As the strongest type of evil womanhood I deal with this woman first. I have neither time nor intention to analyse in full any one character. Only I desire to add one or two suggestions that I think may be new to the analyses already made by others. She appears in act i., scene 5, reading the letter of Macbeth. She is so absorbed in that letter and in her reflexions on it that she makes the only mistake committed by her in the play just after its perusal. The attendant entering with the news: "The King comes here to-night," the words "Thou'rt mad to say it" leap to and from her lips. Truly she tries in the succeeding two lines to tone down the effect inevitably produced by that sudden outburst. But it is very noticeable that the outburst occurred. That once only throughout the play she loses command of herself. Note how different is her questioning answer to Macbeth in the same scene when he makes a like statement. She has wholly recovered herself—is all self-possession.

> *Macb.*—"My dearest love,
> Duncan comes here to-night."
> *Lady M.*—"And when goes hence?"

Turn to act ii., scene 2. Just ere the entry of Macbeth comes the one touch that this man ever gives to his worst characters to make them after all kin to the whole world. She has seen the King lying asleep and has almost done the deed herself.

> "Had he not resembled
> My father as he slept, I had done it."

In that same scene occurs the first foreshadowing of the

sleep-walking scene. The statement has been made that the sleep-walking is unexpected, and is even out of harmony with the nature of Lady Macbeth. Neither statement seems to me accurate. At least, we have in a line in the scene now under consideration, a leading-up to the initial scene of the last act. When her husband tells the story of the murder, how the grooms prayed "God bless us" in their sleep, and "Amen!" and how he could not say "Amen!" she whispers

> "These deeds must not be thought
> After these ways; *so it will make us mad.*"

"Us" not "you."

Her wonderful recuperative power comes out again here. From the horror settling down upon both their lives she is the first to recover. But a few moments after the shivering whisper, "So it will make us mad," she cries, "Give me the daggers," and with a foot that falters never, passes into the death-room and smears the faces of the sleeping servants with the King's blood, yet warm.

(*b*) Ophelia. The mother of Ophelia probably died young. That is to be remembered in estimating the character of this erring sweetness. The mother never appears, is never mentioned in the play. In her mad scene the father and brother are spoken of, but her mother never. And the coarseness of the songs she sings, though perhaps suggestive of that psychological puzzle of which any medical man could give you instances, may point to the fact that her early, impressionable time was spent with servants rather than under the watchful eye of a mother. Consider also what manner of father is hers, in what manner of court she lives. The court full of espials, and the chief spy, Polonius. Let us take these things into account when she makes our hearts ache in the great scene with Hamlet (act iii., scene 1). What an opportunity is hers! A strong, good woman would have saved Hamlet and herself at that interview. Such words of love, and guidance, and strength-giving, would have fallen from her lips. But Ophelia, poor weak one, can only pray. "O, help him, you sweet heavens!" and "Heavenly powers, restore him!" are her last two cries. The help and the restoration should have come from her. They were in her hands. And she can only pray. But, alas! whilst here she is weak, in another part of this same scene she is wicked. She lies to him. Her father is at his old work. He is behind the arras. She knows it. And yet,

when over-anxious at his eavesdropping the grey, dishonorable head is for a moment visible, and Hamlet beholding, with a sudden change of tone asks, "Where's your father?" she answers, "At home, my lord." And this is their last meeting.

(*c*) Miranda. Here also is a girl, a child-woman, who has known no mother. Her sole human companion has been uncompanionable, Prospero. No more delicate drawing has come from the hand of the master, not even in his fairy-pictures than that bestowed on the character of Miranda. A breath of pureness runs through it all. And this when the spirit of his age pointed to and would have encouraged the allusions and double meanings possible, and to some minds conceivable under the like circumstances. Motherless as she has been she has inherited or learned sympathy. At the beginning of act i., scene 2, seeing the storm that her father has raised, she has "suffered with those" she "saw suffer." When he tells her in the same scene of the former troubles when he was banished with her alone;

> "O my heart bleeds
> To think of the teen [sorrow] that I have turned you to."

Very prettily is it suggested in the same scene after the entry of Fernando that she has dreamed of man, and forms other than that of Prospero have visited her in vision.

> "What is it? A spirit?
> Lord, how it looks about! Believe me, Sir,
> It carries a brave form:—but 'tis a spirit."

In act iii., scene 1, with Ferdinand, nothing could be more dainty than her devotion to him. She would even carry his burdens for him. Very charming are the unconscious declaration of her name at the first asking, despite the father's orders, and the modesty visible everywhere, and not least in her exquisite avowal,

> "I am your wife, if you will marry me:
> If not, I'll die your maid: to be your fellow
> You may deny me; but I'll be your servant,
> Whether you will or no."

(*d*) Portia. For wit, humor, gaiety, readiness, high-thinking, queen of women. For her humor take as taste all *her pictures in* act i., scene 2, of the nationalities of Europe,

noting especially the delightful picture of the one-languaged, handsome, idealess, badly-dressed travelling Englishman. And for her readiness and real appreciation of worth and of the necessity of work, her cry after the reading of Antonio's letter in act iii., scene 2. Bassanio has whimpered, vapored, done nothing. She, hearing that pathetic letter, seizes the situation at once, and on her wedding day cries out—

"Oh, love, despatch all business and be gone."

(2) *Men.* (*a*) Iago. To the volumes that have been written on the arch-villain of literature, I add as contributions the following. At the very outset of the play, in its actual opening lines, we find Iago is a borrower from the weakling Roderigo. In that same first scene, he makes that same weakling his cat's-paw. He makes Roderigo begin the arousing of Brabantio. If any blame accrue he secures that it fall on the shoulders of the other. His first words in the ensuing scene reveal him mischief-maker between all men. He can be silent when need is, for during the great scene before the senate, act i., scene 3, wherein the Moor speaks of his services to the State, and claims Desdemona, Iago says never a word. Passing over his temptation, of most devilish order, of Roderigo in the same scene, and the well-known scheming for the misery of Othello, notice one speech in act iv., scene 1, immediately before the entry of Ludovico and Desdemona. Othello with the fatal venom working within him will slay her by poison.

Iago.—"Do it not with poison, strangle her in her bed, even the bed she hath contaminated."

First, that all men may know who is the murderer. If poison be used there may be doubt as to that. Second, that *she* may know. If she die of poison, she will never dream that her beloved has given it to her. Dying she must know that Othello is her slayer, or the cup of horror will not be brimful. Third, that he, Othello, may witness her death. If he give her poison he can disappear and wait its working. But if he strangle her they must be face to face in the last dread moments; each must have the torture of looking into the eyes of that other: he must feel her death struggles and with his huge physical strength fight against the convulsions of her last gasps.

(*b*) Polonius. As unprincipled almost as Iago, but lacking the strength to be as wicked. He is foolish and

Iago is never that. Polonius has long ears from much listening at court key-holes. An utterly selfish man. Even the celebrated advice to his son (act i., scene 3) is purely or impurely selfish. It has not the true ring about it. The third vowel is the centre of it all. Not a generous emotion is stirred by it. In thorough keeping with this is the commencement of the first scene of the second act. He sets on Reynaldo, the servant, to play the spy upon Laertes abroad and report to his excellent father, Polonius. He proposes in the next scene that the king and he should be "behind an arras" when the interview between his daughter and Hamlet takes place. This proposal he actually carries out. And in act iii., scene 4, he dies as he has lived—an eavesdropper, run through by the sword of Hamlet as he listens to an interview between mother and son.

(*c*) Brutus. With relief I turn from these evil men, and passing over the weak folly of an Aguecheek, the genial, delightsome rascality of a Falstaff, the warrior Othello, the student Hamlet, the Titans, Shylock and Lear, deal in the little time left to me with the highest type of man, as it seems to me that our Shakspere has drawn. That type is met with in the republican Brutus. I call him also Atheist. Once truly in the play (act ii., scene 1) he calls upon the gods to render him "worthy of his noble wife." But throughout it elsewhere, under trials and emotions that would have forced a believer in the gods to appeal times and again to them, no such appeal is made. He bears the news of Portia's death not unmoved, but without a reference to the supernatural. He looks on Cassius dead, he looks his own death in the face, and the name of no god escapes his lips. Let us look a little at this notable man. He loves Cæsar. Ah, how he loves him. Far more than any other living being save only Portia. Portia he loves better than Cæsar. Rome he loves better than Cæsar. His own honor also is dearer to him. Act i., scene 1, the shout of the populace goes up.

> "I do fear the people
> Choose Cæsar for their king."

He loves openness wherever it is possible. The dark hints of Cassius drive him to clear questioning.

> "What is it that you would impart to me?
> If it be aught toward the general good,
> Set honor in one eye and death in the other,
> *And I will* look on both indifferently:

For let the gods so speed me, as I love
The name of honor more than I fear death."

He has thought long and sadly of these times: more than any other man in Rome. Listen to him thinking aloud in the soliloquy in act ii., scene 1. The conspiracy is necessary, but in what noble wise he conducts himself therein. Cassius would "swear our resolution." Brutus cries aloud "No, not an oath." He has no belief in such appeals to the supernatural amongst honest men.

"What other oath
Than honesty to honesty engaged
That this shall be or we will fall for it?"

When the rest would go further in killing than Cæsar he interposes. Antony's life is saved by him. Cæsar must be slain, alas! But none other need be.

"Let us be sacrificers and not butchers, Caius Cassius."

What hold he has on all men! Liguarius, in the garden scene, though sick, leaves his bed at the call of Brutus, discards his weakness and will work at his bidding.

In the murder scene, act iii., scene 1, while all the other conspirators crowding round Cæsar pray with words their prayer, Brutus alone kisses his hand. It is no Judas' kiss. It is farewell!

And, finally, if we turn to act iv., scene 1, and study him under the shadow of the death of Portia, the same greatness meets us. The quarrel with Cassius is over. Consider the lesson to us all in that quarrel. Cassius has said bitter things—very bitter, and he knows not until *after they are said* that Brutus has but now lost Portia. "Portia is dead," says Brutus.

Cas.—"Ha! Portia?
Bru.—She is dead."

He tells the manner of her death, and to the question of Cassius, "And died so?" answers "Even so." In the council scene that follows, Messala, who has had letters from Rome that tell of Portia's death, is ignorant that Brutus knows thereof. There is a strange pathos therefore in the talk. For Brutus, hoping against hope, is, by the doubtful queries of his friend, half led to distrust his earlier news. Hence with redoubled force comes its confirmation.

Still he is patient, and turns, as all men and women turn that are strong, to the panacea, work.

"Well to our work alive."

His last words are full of a sublime dignity, very touching. The actual ending is

"My bones would rest,
That have but labored to attain this hour."

This hour is the hour of death, the goal of all labor, the crown of all ambition.

Let us end our study of this man in the words of his conqueror Antony:

"This was the noblest Roman of them all:
* * * * *
His life was gentle; and the elements
So mix'd in him that Nature might stand up,
And say to all the world,
'This was a man.'"

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LECTURE IV.

VI. CHARACTERS (continued). (3). *Children.* In the plays of our foremost dramatist but few children appear. From the acting point of view this is not on the whole to be regretted. For the child-actor is, as a rule, a repellant creature. A child young enough to look the part and yet self-possessed enough to appear on a stage, without the self-possession becoming self-consciousness, is almost an impossibility. This difficulty may have been the reason why Shakspere rarely introduces child characters. The reason cannot be any difficulty in their delineation. For, from the literary point of view, his children are as excellent, as real as their grown-up companions. His children *are* children, and as Boots at the Holly-Tree Inn says, "It's to be wished more of 'em were." Let us consider two youthful characters.

(*a*) Prince Arthur. The child-king meets us first in act ii., scene 1. He speaks twice only in the long scene. Once at the commencement he, in formal words falling idly in prepared phraseology from the young lips, bids the Archduke of Austria welcome. Later when the royal quarrels run high, and hard words—prelude to hard blows—are bandied about, he cries out—

> "I would that I were low laid in my grave,
> I am not worth this coil that's made for me."

The boy cares for none of these things. He would rather a thousand times be at play with his comrades than thus the centre of contending kings and queens and armed men. The whole transaction is to him a bore and a distress. In act iii., scene 3, the child nature, with its deep affection for mother Constance, speaks out in the phrase that breaks from him when the fight is lost and he is prisoner of John and grandam Elinor.

> "O this will make my mother die with grief."

There is no cry on his own behalf, prisoner though he be. The *anxiety* is for her. And all through the familiar

scene with Hubert, the first in act iv., the boy is a boy. The curious habit of over-refining similes, so prevalent in the older times, helps to mar in one or two cases the intense reality of the scene, as in the speeches that deal with the red-hot iron rusting from his tears and with the extinct fire. But, ignoring these, how fresh and boy-like are the opening talk with the innocent pathos of the "I remember, when I was in France," the swiftness of his perception of Hubert's altered mien, the tenderness of his pleading and how terrible is the child's scream, "O save me, Hubert, save me!" on the entry of the executioners. Noble and yet childlike once again are the resolve and the promise to "stand stone-still" and bear all, if only he is left alone with Hubert.

(*b*) Lucius. In "Julius Cæsar" we meet this charming boy. The charm of his open, untroubled boy-nature deepens by contrast with the strength of the man Brutus, sorely tried by vast mental conflict. This boy Lucius plays around the circumference of great things of which his master is the centre. He is all unconscious of the storm that rages hard by. He is the rainbow on its fringe. In act ii., scene 1, he is asleep while Brutus strides restless to and fro in his orchard under the solemn stars, and cloaked conspiracy steals through the streets of Rome. What a sleepy yawn is there in his first speech, when the voice of Brutus wakes him!

"Call'd you, my lord?"

Sent to the study for a taper he returns to tell us that he has been "searching the window for a flint." That flint has a regular place, you may be sure. It was not in its regular place. Master Lucius has had to "search" for it. The window is not its customary *locale*. Probably the same careless little hand that now finds it in this unusual position placed it there earlier in the evening. Asked by Brutus what is the day of the month, he knows not. Why should he? What boy ever did except in the last three or four weeks of his school term? Lucius has left school, and he is wholly ignorant of the month's age. He has no appointments to keep, no bills to meet. In the 4th scene of the same act he is with Portia in the streets of Rome on the murder-day. She is distraught with nervous anxiety. *Brutus* is yonder. Cæsar is even now face to face with *death*. But the boy, open-eyed, is easy and unperturbed,

and when her disordered fancy translates the passing wind. into "a bustling rumor, like a fray," he hears nothing In the final part of the one scene that constitutes the whole of the fourth act, we have Lucius with Brutus on the last night of that "greatest Roman of them all." Awakened to bear in the bowl of wine in which the two friends drown all memory of their quarrel, he dozes through the council scene and at its end brings the gown to his worn out lord. In its pocket Brutus finds the book as to the whereabouts of which there have been between Lucius and himself little differences of opinion. To him falls now the rare privilege, often recalled by him in after years, of soothing the sad heart of Brutus with music. It is his duty; he is only too willing to do it, late as is the hour, for Brutus' sake; nay, he has slept already. And so he plays until he falls asleep again. I have said he will recall in later times that evening. Not the least memorable part of it will be the touch of his master's hand upon his young head, the look of his master's eyes deep down into his upturned, the sound of the voice that said,

"If I do live
I will be good to thee."

(4) *The Clowns.*—The comic characters of Shakspere, it has been said, present three chief types. Lowest ranks the coarsely humorous clown, as Launce, or Dogberry. Highest ranks the witty and refined type represented by the Fool in Lear. Between these comes an intermediate class possessed in some degree of the rougher mirth-moving qualities but gifted also with the rarer wit. Of this ilk is Shylock's servant, Launcelot Gobbo. (*a*) In my illustrations of humor I made reference to Dogberry, who may be taken as type of the first set. Not a thing he says is intrinsically worth remembering. But the relative and absolute absurdity of the things he says, and the coarse folly of the man, move us to laughter.

(*b*) Launcelot Gobbo. The second scene of the second act opens with his soliloquy. Inclination draws him one way —from the Jew. Duty draws him in the opposite direction —to the Jew. Like all low natures, he personifies his emotions. Inclination is to him the fiend. Duty is to him conscience. With much humor he enacts the struggle between them to its inevitable ending in the triumph of inclination. There is true humor here, and humor, of a

sort, in the practical joke played immediately afterwards upon his purblind father. With all this the harping upon the grand word "Ergo" is in excellent keeping. But there is one touch in this duologue between father and son, of which Dogberry and his school are not capable. After his thoughtless pranks with the old man, wherein he pretends that he, *videlicet* Launcelot, is dead, he finds difficulty in making the elder believe that all has been a joke. "Pray you, let's have no more fooling about it, but give me your blessing. I am Launcelot, your son that was, your boy that is, your child that shall be." In that last phrase is there not confession of past folly and promise, even if it be ill-kept, of better conduct in the future? And in his passage of arms with Lorenzo in act iii., scene 5, there is much more than mere humor. Whilst, as final and conclusive evidence that this man is of far better nature than the stolidly stupid clowns, notice that he is the go-between of the lovers. Even Lorenzo and Jessica would not have chosen him for this had there not been something in the man.

(*c*) Of the third and highest class are Touchstone in "As You Like It," and the fool in "Lear." The former as the banished duke hath it, "uses his folly like a stalking horse, and under the presentation of that he shoots his wit." To all and sundry with whom he comes in contact, he gives some rub. Even to Celia it comes in act i., scene 2, through the medium of a slight upon her father. He has spoken of the knight who swore by his honor, and breaking faith was not foresworn, as he had no honor. Questioned as to who the knight was, he answers, "One that old Frederick, your father, loves." Rosalind herself, in act iii., scene 2, he teases with a ready burlesque of the love verses she has found hung "on a palm tree." And for his wit at its best, for we care not how hard is the hitting here, turn to act v., scene 4, where he hits off the character of the courtier in an assembly of quondam courtiers, ridicules the quarrels and combats of the age to the face of men who have had their share of these, and quells even Jaques Cynic who would catch him tripping, "Oh, Sir, we quarrel in print, by the book; *as you have books for good manners.*"

The fool in "Lear" ranks even more highly than Touchstone. That there is in him a finer feeling is shown by the lines that introduce us to him. "Since my young lady's *going into* France, Sir, the fool hath much pined away."

He, entering just upon this speech, hires Kent, and gives, as earnest, his cockscomb, for Kent has befriended Lear, the king. To Lear, a little later, he gives his cockscomb and bids him beg another of his daughters (act i., scene 4), for he must needs have two, as in regard to two daughters he has shown his folly. And even the poor right to wear these he must beg of Regan and Goneril. In the sixth scene of act iii., that dread scene in which within the hovel, the king goes through the mock of a trial of his daughters, when worn out of madness, Lear cries, "Make no noise, make no noise; draw the curtains: so, so, so; we'll go to supper in the morning; so, so, so," the fool with a voice, I take it, half broken with sobs, answers, "And I'll go to bed at noon." These are his last words in the play, and he dies ere the end of it—dies young. "And I'll go to bed at noon."

(5) *Supernaturals.* It is wholly needful to remember that in Elizabethan days the supernatural was accredited. How much or how little Shakspere believed therein matters little. His audiences were believers. Whilst this fact must be kept in mind when we study "Macbeth" and "The Midsummer's Night's Dream" it is equally needful in dealing with the first instance that we take to remember that the supernatural is ever the reflex of the natural and not its cause. (*a*) The Witches. These are in some sort the thoughts of Macbeth embodied. Of them he takes counsel in all great crises. Look at the end of act i., scene 1. Its last line but one is,

"Fair is foul and foul is fair."

Look at Macbeth's initial lines as he enters in scene 3.

"So foul and fair a day I have not seen."

His opening words in the letter to his wife are,

"*They* met me in the day ot success."

(*b*) The Ghost in Hamlet. I have but space to deal with two dramatic points here. In act i., scene 1, Bernardo relieves Francisco on his watch. All has been quiet. "Not a mouse stirring." And yet Francisco is "sick at heart." A nameless something-nothing oppresses him. The Ghost is in the air. In the same scene, mark with what skill the entry of the Ghost is managed. The doubting Horatio and the two who have seen are on the ramparts at Elsinore.

Bern. "Last night of all
When yon same star, that's westward from the pole,
Had made his course to illume that part of heaven

> Where now it burns, Marcellus and myself,
> The bell then beating one—
>
> *Mar.* Peace! break thee off; look where it comes again!"

"Last night." In the two mere words is something ghostly. "Yon same star." It shines on them even now. "Where *now* it burns." "Marcellus and myself." These two are by the side of Horatio. "The bell then beating one." Boom! goes out the sound from a castle turret and the Ghost glides on.

(*c*) The Fairies. The man who has given us the strength of Othello, the intensity of Lady Macbeth, the passion of Lear, gives us also the dainty delicacy of Puck and Titania. Were ever such fairies as these outside fairyland?

> "Over hill, over dale,
> Thorough bush, thorough brier,"

sings the first of them in act ii., scene 1, and to her airy song Puck answers with account of the quarrel between Oberon and Titania, a quarrel in consequence of which

> "All their elves, for fear,
> Creep into acorn-cups and hide them there."

Don't you see their bead-eyes with a half-serious laugh in them peeping just over the edge of an acorn-cup? Even more graceful and fairy-like than this is a line in act iii., scene 1. Titania, enamored most unhappily of Bottom, calls four fairies to her. To Peas-blossom, Cobweb, Moth and Mustard-seed she commends him.

> "Pluck the wings from painted butterflies,
> To fan the moonbeams from his sleeping eyes."

That last line is to me unequalled in literature for exquisite delicacy. And who can leave Titania and the Weaver without noting the pathos of it all. Not that he is a weaver. A thousand times over, No. But he is conceited, coarse Bottom. Not that he is a workman. But he is an arrogant braggart. And she loves him. Is there not a human pathos in this? Is not the same story going on behind the walls and windows of a thousand houses in this city to-night? Note what the flower is that works this ill. *Love-in-idleness.* Not the love that dawns and grows when men and women are at honest, noble work. Love, in idleness.

(*d*) Caliban. This strange creation is link between the supernatural and the natural, or perhaps more accurately *between* man and brute. That Prospero's treatment of him

is roughness itself can hardly be denied; and even when he enters with the bitter curses on father and daughter alike, one is fain to remember that he has but bettered the instruction of the former. Nowhere, perhaps, does the brute nature come out with more appalling force than in the animal roar in his answer to Prospero's reminder of his attempt upon Miranda.

> "O ho, O ho! would it had been done!
> Thou didst prevent me; I had peopled else
> This isle with Calibans."

And yet in this strange being there exist the germs of better things. When you, Prospero, taught me the names and natures of things "then I loved thee." Stephano, drunken butler as he is, to Caliban becomes an object of worship. He has the power of reverence, and what hope is in man then! Truly it is misdirected and is marred by the early blunder so universal in lower human races; the blunder that invents the supernatural, and labels it "god." But the capacity for reverence is there.

> "That's a brave god and bears celestial liquor:
> I will kneel to him."

And let us notice the remarkable speech of act iii., scene 2:—

> "The isle is full of noises,
> Sounds, and sweet airs that give delight and hurt not,
> Sometimes a thousand twangling instruments
> Will hum about mine ears; and sometimes voices,
> That if I then had waked after long sleep,
> Will make me sleep again: and then, in dreaming,
> The clouds, methought, would open and show riches
> Ready to drop upon me; that when I waked
> I cried to dream again."

VII. The Last Play. As we close this our brief study of his writings, let us take that of which there is such strong evidence as an assured thing. Let us accept the "Tempest" as his last play. In this, that is as usual tragedy, comedy, farce, all in one, his dramatic construction is at its ripest. Here is all the strength of his mature years. But the strength is mingled with the ineffable charm and grace of his earlier time. The characters are as clearly marked, as real as the men and women of the great tragic plays. Excellent old Gonzago, delicious Miranda, Ariel, delicate as the rainbow made in the spray of a waterfall, live in this final work. And the scene is in an enchanted island. We turn from the

courts, and camps, and cities, and hear his last charming on Prospero's isle. It reminds us of old Sir John falling a babbling of green fields as the end came. And when we study the play in this connexion, what a deep solemnity sounds in the lines—

"But this rough magic
I here abjure: and when I have required
Some heavenly music (which even now I do)
*   *   *   I'll break my staff,
Bury it certain fathoms in the earth,
And deeper than did ever plummet sound
I'll drown my book."

Is not the music that of human laughter and tears heard through the centuries? And now that we turn from him and his, and no more for a while, walk hand in hand through his fairy-land, now that we part company, and may no longer look together on the faces of his men and women, as we think of these, of him, of ourselves, the words of Prospero sound in our ears as though afar off, and reaching us from the enchanted island—

"These, our actors,
As I foretold you, were all spirits, and
Are melted into air, into thin air:
And, like the baseless fabric of this vision,
The cloud-capped towers, the gorgeous palaces,
The solemn temples, the great globe itself,
Yea, all which it inherit, shall dissolve;
And, like this insubstantial pageant faded,
Leave not a rack behind. We are such stuff
As dreams are made of, and our little life
Is rounded with a sleep."

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LECTURE I.

"The question of questions for mankind—the problem which underlies all others and is more deeply interesting than any other—is the ascertainment of the place which man occupies in nature and of his relation to the universe of things. Whence our race has come; what are the limits of our power over nature, and of nature's power over us; to what goal we are tending; are the problems which present themselves anew and with undiminished interest to every man born into the world."—*Huxley*, "Man's Place in Nature."

ANTHROPOLOGY is an old compound of two Greek words signifying the science of man, and as formerly very distinct lines were drawn by those in authority between moral man and physical man, it was first used to denote the study of man moral; afterwards the study of man physical; then to include both. Denying the possibility of any absolute division lines between man moral and man physical, I should simply define Anthropology as the "science of man." Dr. Paul Broca defines Anthropology as "a science which has for its object the study of the human race, considered as a whole, in its separate individuality, and in its relations with the rest of nature." The Anthropologist considers: (1) Man in his *ensemble* so far as the group to which he belongs differs from, or is analogous to, contiguous groups in the class of mammalia to which he is in nearest relation. (2) The varieties of mankind. These varieties are commonly called races. Much difference of opinion will be found on the word race, type, species. Prichard defined "species" to mean "separate origin and distinctness of race evinced by a constant transmission of some characteristic peculiarity of organisation," and Gliddon regarded "types" as "those primitive or original forms which are independent of climatic or physical influences," and he added that "all men are more or less influenced by external causes, but these can never act with sufficient force to transform one type into another." It seems now, however, pretty clear that there are no forms or characteristic peculiarities which ought to be regarded as completely independent of climatic and physical influences.

Anthropology includes inquiry (1) into the comparative anatomy and morphology of man and other animals, especially of the mammalia, and amongst these particularly the anthropoid apes; (2) the history of all these; (3) prehistoric archæology in its bearing on them; (4) physiology, including in this psychology in health and disease. Although the study of man may be traced back to the period of the earliest efforts of the human mind, anthropology as a special science only belongs to the last quarter of a century.

The late Dr. James Hunt, to whose energy and unselfish devotedness the study of anthropology owes very much in this country, divided anthropology into physio-anthropology, or the doctrine of the functions of mankind, and morpho-anthropology or the doctrine of the forms of mankind. He argued that anthropology being part of biology, and biology being divided into morphology, or the doctrine of form and physiology, or the doctrine of function, a similar division was not unnatural in anthropology.

A fair statement of the width of this subject, and of the difficulties at present connected with its study, may be found in the following extract from the address delivered by Prof. W. H. Flower, the president of the Anthropological Section at the York meeting of the British Association:—

"The study of the true relationship of the different races of men is not only interesting from a scientific point of view, but of great importance to statesmanship in such a country as this, embracing subjects representing almost every known modification of the human species, whose varied and often conflicting interests have to be regulated and provided for. It is to want of appreciation of its importance that many of the inconsistencies and shortcomings of the government of our dependencies and colonies are due, especially the great inconsistency between a favorite English theory and a too common English practice—the former being that all men are morally and intellectually alike, the latter being that all are equally inferior to himself in all respects; both propositions egregiously fallacious. The study of race is at a low ebb indeed, when we hear the same contemptuous epithet of 'nigger' applied indiscriminately by the Englishmen abroad to the blacks of the West Coast of Africa, the Caffres of Natal, the Lascars of Bombay, the Hindus of Calcutta, the Aborigines of Australia, and even the Maoris of New Zealand. But how is he to know better? Where in this country is any instruction to be had? Where are the books to which he may turn for trustworthy information? The great work of Pritchard, a com-

pendium of all that was known at the time it was written, is now almost entirely out of date. In not a single University or public institution through the three kingdoms is there any kind of systematic teaching, either of physical or of any other branch of anthropology, except so far as comparative philology may be considered as bearing upon the subject. Though the study of man's origin and the earliest appearances upon the earth, and that of the structural modifications to which in course of time he has arrived, or the study of races, are ultimately related, and will ultimately throw light upon one another, I venture to think that the latter is the more pressing of the two, as it is certainly the more practically important; and hence the necessity for greater attention to physical anthropology. In seeking for a criterion upon which to base our study of races, in looking for essential proofs of consanguinity of descent from common ancestors in different groups of men, we must first look to their physical or anatomical characters, next to their moral and intellectual characters—for our purpose more difficult of apprehension and comparison—and, lastly, as affording hints, often valuable in aid of our researches, but rarely to be depended upon, unless corroborated from other sources, to language, religion, and social customs. The study of the physical or anatomical character of the races of man is unfortunately a subject beset with innumerable difficulties. It can only be approached with full advantage by one already acquainted with the ordinary facts of human anatomy, and with a certain amount of zoological training. The methods used by the zoologist in discriminating species and varieties of animals, and the practice acquired in detecting minute resemblances and differences that an ordinary observer might overlook, are just what are required in the physical Anthropologist. As the great problem which is at the root of all zoology is to discover a natural classification of animals, so the aim of Zoological Anthropology is to discover a natural classification of man. A natural classification is an expression of our knowledge of real relationship. When we can satisfactorily prove that any two of the known groups of mankind are descended from the same common stock, a point is gained. The more such points we have acquired, the more nearly shall we be able to picture to ourselves, not only the present, but the past distribution of the races of man upon the earth, and the mode and order in which they have been derived from one another. The difficulties in the way of applying zoological principles to the classification of man are vastly greater than in the case of most animals, the problem being one of much greater complexity. When groups of animals become so far differentiated from each other as to represent separate species, they remain isolated; they may break up into further subdivisions—in fact, it is only by further sub-division that new species can be formed; but it is of the very essence of species,

as now universally understood by naturalists, that they cannot re-combine, and so give rise to new forms. With the varieties of man it is otherwise. They have never so far separated as to answer to the physiological definition of species. All races are fertile one with another, though perhaps in different degrees. Hence new varieties have constantly been formed, not only by the segmentation, as it were, of a portion of one of the old stocks, but also by various combinations of those already established."

The best text-book in English for the student of Anthropology is the work by Dr. Paul Topinard, with a preface by Professor Paul Broca, translated into English by Dr. Barclay. This work I have most utilized in these lectures. Some valuable information will be found in Professor Huxley's "Man's place in Nature," and in the lectures by L. Geiger on the "History of the Development of the Human Race," which have recently been translated by Dr. Asher. Abel Hovelacque on the Science of language, and the treatise on Biology by Dr. Chas. Letourneau, the latter translated by William Maccall, will be found very useful to Anthropological students. Nott and Gliddon's "Types of Mankind" and "Indigenous Races of the Earth," have special value as containing references to nearly every important writer on Ethnological points up to the dates of their respective publications.

Ethnology treats of the origin and distribution of peoples. Ethnography, with the description of each people, of its manners, customs, religion, language, physical characteristics, and origin in history. Both are necessary to Anthropology. Dr. Bertillon divided Anthropology into three divisions: Analytical Anthropology, or Ethnology, which, with Ethnography, furnishes the materials for the other two divisions, viz., Synthetic or General Anthropology, and Philosophic Anthropology.

With reference to the origin of man, the one view—that of the monogenist as Pritchard or Quatrefages—was that all races, as we see them now, are the descendants of a single pair who, in a comparatively short period of time, spread over the world from one common centre of origin, and became modified by degrees in consequence of changes of climate and other external conditions. The other—that of the polygenist, as Louis Agassiz—is that a number of varieties

or species have independent centres in different parts of the world, and have perpetuated their original distinctive characters. Agassiz, Gliddon, Nott, having in view the very few thousand years then claimed by the Churches for man's existence on earth, contended that the ordinarily accepted time was insufficient for the development of known diversities of type, and they maintained that type was permanent under the conditions in which we found it, and must therefore have originally been multiple. But two features have now to be considered which were then excluded: one, the admittedly huge period of time man has inhabited the earth; the other, the light resulting from the untiring labors of Darwin in the path opened out by Lamarck and somewhat hesitatingly trodden by Wallace.

The doctrine of "transformism," says Topinard, is

"due to Lamarck, although De Maillet and Robinet had previously sketched out some of its traits. A species, Lamarck wrote in 1809, varies infinitely, and, considered as regards time does not exist. Species pass from one to the other by an infinity of transitions, both in the animal and vegetable kingdom. They originate either by transformation or divergence. By going back for ages, we thus come to a small number of primordial germs or monads, the offspring of spontaneous generation. Man is no exception to this; he is the result of the slow transformation of certain apes. The ladder, to which we before compared the organic kingdom, only exists, he says, as regards the principal masses. Species, on the contrary, are, as it were, the isolated extremities of the branches and boughs which form each of these masses. . . . . The ways and methods of Lamarck may be summed up in a single sentence—the adaptation of organs to conditions of existence. Change in external circumstances, he says, obliges the animal placed in the presence of animals of greater strength, or in new conditions of life, to contract different habits, which produce an increased activity in certain organs, a diminution, or a want of exercise, in others. By virtue of the physiological law inherent in every organism, that the organ, or a certain part of the organ, diminishes or increases in proportion to the work that it performs, these organs become modified when submitted to new conditions. The internal power of the organisation dependent on the general function of nutrition which is called forth is immense. The wants induced by external changes brought it into play."

But Lamarck's doctrine, fifty years before its time, was laughed down and sneered down. Now it is triumphant in Darwinism, which, says Topinard, may be defined as

"Natural selection by the struggle for existence applied to the transformism of Lamarck."

Professor Flower, in the address from which I have already quoted, contends that

"the view which appears best to accord with what is now known of the characters and distribution of the races of man, and with the general phænomena of nature, may be described as a modification of the monogenistic hypothesis. Without entering into the difficult question of the method of man's first appearance upon the world, we must assume for it a vast antiquity, at all events, as measured by any historical standard. Of this there is now ample proof. During the long time he existed in the savage state—a time compared to which the dawn of our historical period was as yesterday—he was influenced by the operation of those natural laws which have produced the variations seen in other regions of organic nature. The first men may very probably have been all alike; but when spread over the face of the earth and become subject to all kinds of diverse external conditions—climate, food, competition with members of their own species or with wild animals—racial differences began slowly to be developed through the potency of various kinds of selection, acting upon the slight variations which appeared in individuals in obedience to the tendency implanted in all living things. Geographical position must have been one of the main elements in determining the formation and the permanence of races. Groups of men isolated from their fellows for long periods, such as those living on small islands, to which their ancestors may have been accidentally drifted, would naturally, in course of time, develop a new type of features, of skull, of complexion or hair. A slight set in one direction in any of these characters would constantly tend to intensify itself, and so new races would be formed. In the same way different intellectual or moral qualities would be gradually developed and transmitted in different groups of men. The longer a race thus formed remained isolated, the more strongly impressed and the more permanent would its characteristics become, and less liable to be changed or lost, when the surrounding circumstances were altered, or under a moderate amount of intermixture from other races—the more 'true,' in fact, would it be. On the other hand, on large continental tracts, where no 'mountains interposed make enemies of nations,' or other natural barriers form obstacles to free intercourse between tribe and tribe, there would always be a tendency towards uniformity, from the amalgamation of races brought into close relation by war or by commerce. Smaller or feebler races have been destroyed or absorbed by others impelled by superabundant population or other causes to spread beyond their original limits; or sometimes the conquering race has itself dis-

appeared by absorption into the conquered. Thus, for untold ages, the history of man has presented a shifting kaleidoscopic scene; new races gradually becoming differentiated out of the old elements, and, after dwelling awhile upon the earth, either becoming suddenly annihilated or gradually merged into new combinations; a constant destruction and reconstruction; a constant tendency to separation and differentiation, and a tendency to combine again into a common uniformity—the two tendencies acting against and modifying each other. The history of these processes in former times, except in so far as they may be inferred from the present state of things, is a difficult study, owing to the scarcity of evidence. If we had any approach to a complete palæontological record, the history of man could be reconstructed; but nothing of the kind is forthcoming. Evidences of the anatomical characters of man, as he lived on the earth during the time when the great racial characteristics were being developed, during the long ante-historic period in which the Negro, the Mongolian, and the Caucasian were being gradually fashioned into their respective types, is entirely wanting, or, if any exists, it is at present safely buried in the earth, perhaps to be revealed at some unexpected time, and in some unforeseen manner. It will be observed, and perhaps observed with perplexity by some, that no definition has as yet been given of the oft-recurring word 'race.' The sketch just drawn of the past history of man must be sufficient to show that any theory implying that the different individuals composing the human species can be parcelled out into certain definite groups, each with its well-marked and permanent limits separating it from all others, has no scientific foundation; but that, in reality, these individuals are aggregated into a number of groups of very different value in a zoological sense, with characters more or less strongly marked and permanent, and often passing insensibly into one another. The great groups are split up into minor subdivisions, and filling up the gaps between them all are intermediate or intercalary forms derived either from the survival of individuals, retaining the generalised or ancestral characters of a race from which two branches have separated and taken opposite lines of modification, or from the reunion of members of such branches in recent times. If we could follow those authors who can classify mankind into such divisions as trunks, branches, races, and sub-races, each having its definite and equivalent meaning, our work would appear to be greatly simplified, although, perhaps, we should not be so near the truth we are seeking. But being not yet in a position to define what amount of modification is necessary to constitute distinction of race, I am compelled to use the word vaguely for any considerable group of men who resemble each other in certain common characters transmitted from generation to generation."

Anthropology more than any other science finds itself in conflict with religious and political institutions. In its researches into man's nature and the *mobile* of his acts, passions, and wants in the past, of his progress to civilisation, of the hindrances in his path, and of his future possibilities it cannot avoid clashing with the teachings which religious authorities have established in accord with what they possibly considered the best interests of human kind. In its enquiries into distribution of peoples it occasionally comes into contact with nationality delusions fostered by political leaders in view of the exigencies of statecraft. Anthropology is the great social science: in its completeness alone will any approach to real moral law be possible. To know what man should do it is first necessary to know what man is, and what it is he can do.

The science of acclimitisation is one of the departments of Anthropology, and an especially useful one when the white races under the pressure of population are seeking to colonise in every part of the world. Man apparently in the end inures himself to almost every climate, but only after great struggling. One race has a tendency to die out in a country where another thrives easily.

"It is undeniable," says Dr. Topinard, "that man by a certain method of high breeding and well-managed crossing is capable of being changed in successive generations in his physical as well as in his moral character. According to the modes adopted he will go on either degenerating or improving. Anthropology comes in here with the highest, and at the same time most practical aim, and its utility in this alone should secure for it the encouragement and patronage of our learned societies."

Linnæus placed man, the monkey, and the bat in one and the same order, named primates. This zoological classification which put man at the head of the series of animated beings shocked the orthodox, and Cuvier placed man in one order by himself; the monkey, in a second order; the bat in a third.

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LECTURE II.

Is the animal man something apart from all other animals or is he one in the animal scale only distinguished by superiority of gradation? As Huxley asked eighteen years ago—

"Is he something apart? Does he originate in a totally different way from dog, bird, frog and fish, thus justifying those who assert him to have no place in nature and no real affinity with the lower world of animal life? Or does he originate in a similar germ, pass through the same slow and gradually progressive modifications—depend on the same contrivances for protection and nutrition, and finally enter the world by the help of the same mechanism? The reply is not doubtful for a moment, and has not been doubtful any time during the last thirty years. Without question the mode of origin and the early stages of the development of man are identical with those of the animals immediately below him in the scale:—without a doubt in these respects he is far nearer the apes than the apes are to the dog."

And again he declares—

"That the structural differences between man and the highest ape are of less value than those between the highest and lowest ape."

And here it must not be forgotten that of the man who inhabited Europe before the Aryan immigration overran it, we have at present no means of making comparison; the lowest man is known to us by traces only, and these sometimes of the faintest and most indistinct character.

At the outset man starts in life as do other vertebrates—as was pointed out many years ago by the author of "The Vestiges of Creation." In every vertebrate animal we begin with the egg, having the same essential structure, and as Huxley tells us, there is a period in which the young of all these animals resemble one another, not merely in outward form, but in all essentials of structure so closely, that the

differences between them are inconsiderable, while in their subsequent course they diverge more and more widely from one another. Man is no exception. "Identical," says Huxley, "in the physical process by which he originates—identical in the early stages of his formation—identical in the modes of his nutrition before and after birth, with the animals which lie immediately below him in the scale. Man, if his adult and perfect structure be compared with theirs, exhibits, as might be expected, a marvellous likeness of organisation."

In a later work on the anatomy of vertebrate animals, Professor Huxley, after a careful description of the brain, says: "In all the characteristics now mentioned the brain of man differs far less from that of the chimpanzee than that of the latter does from the pig's brain."

The physical characters of the human group are of two orders; some organic, to be studied on the skeleton and on the dead body: others physiological, to be studied on the living. As a frontispiece to "Man's Place in Nature," we have the skeletons of man, gorilla, chimpanzee, orang, and gibbon. Here, besides the shape of head, the greater length of arm, the slightly shorter leg, in relation to the spine, and greater size of hand and foot, are the striking features in the ape. For example, taking the spinal column of the gorilla at a nominal 100, its arm equals 115 as against European man's 80; its leg 96, as against the man's 117; its hand 36, the man's 26; its foot 41, the man's 35. While there are many other osteological points of interest pointed out in Dr. Topinard's book, limited space confines us here to the cranium. The cranium is formed of two portions in all mammalia, the cranium proper, or skull, the receptacle of the brain; and the face, the receptacle of the principal organs of sense and of the masticatory apparatus. Their development is in an inverse ratio, and so is their respective situation in reference to that development. In man the cranium is large, and is placed above the face; in quadrupeds it becomes less, and slopes more rapidly backwards; in monkeys the size and situation of the cranium are intermedial.

Comparison of craniums has been carried on to a large extent, so far as concerns man and the other leading animals. This comparison has been especially directed to the facial

angle and cranial capacity. There are four well-known facial angles:—1. Camper's angle; 2. Jacquart's angle; 3. Angle of Geoffroy St. Hilaire and Cuvier; 4. Cloquet's angle. Dr. R. S. Charnock, president of the late London Anthropological Society, urges that while Camper's method may be useful enough for its original purpose, it is of little or no use to the Anthropologist in the diagnosis of race characters, or in comparing the development of the face with that of the brain.

Cloquet's angle is the only one which will be used here to illustrate cranial differences between an European, a Negro, an infant chimpanzee, a full grown chimpanzee, a male gorilla, and a Newfoundland dog.

Native of Lower Brittany	72·0
Namaquois Negro	56·0
Infant chimpanzee, first dentition	51·5
Chimpanzee	38·6
Male gorilla	31·0
Newfoundland dog	24·5

The facial angle is an important characteristic of comparison between man and other animals. But it expresses rather the absolute development of the face, than the relation of the size of the face to the size of the cranium. In man the face is small and short, in the Newfoundland dog it is longer and flatter.

In cranial capacity, arrived at by filling the skull cavity with small shot or seed, there is a very gradual rise from the dog to the gorilla, and then a great leap from the gorilla to man. From a variety of experiments by Carl Vogt and by Dr. Topinard, it is estimated that the capacity in man of the cranial cavity, and consequently of the volume of the organ it encloses, is nearly three times larger than that of the gorilla.

Dr. Topinard thinks that taking the relative bulk of body into account, the degree of superiority should be rated still higher. Huxley calculated that the lowest man's skull has twice the capacity of that of the highest gorilla. But, he added, that in noting this very striking difference, it should be borne in mind—

"That the difference in the volume of the cranial cavity of different races of mankind is far greater, absolutely, than that

between the highest ape and the lowest, while relatively it is about the same. For the largest human skull measured by Morton, contained 114 cubic inches, that is to say, had very nearly double the capacity of the smallest; whilst its absolute preponderance of 52 cubic inches is far greater than that by which the lowest male human cranium surpasses the largest of the gorillas; secondly, the adult crania of gorillas which have yet been measured differ among themselves by nearly one-third, the maximum capacity being 34·5 cubic inches the minimum 24 cubic inches; and thirdly, after making all due allowances for difference of size, the cranial capacities of some of the lower apes fall nearly as much, relatively, below those of the higher apes as the latter fall below man. Thus, even in the important matter of cranial capacity, men differ more widely from one another than they do from the apes; whilst the lowest apes differ as much in proportion from the highest as the latter does from man."

There is a remarkable difference of natural posture. Man alone stands perfectly upright; the anthropoid apes have an oblique or side movement in progressing; the other mammalia have a horizontal attitude.

The upright attitude of man has an important bearing on our present inquiry. Says Topinard:—

"The head, in all the mammalian series, is articulated with the vertebral column by means of the condyles of the occipital which rotate from before backwards and from behind forwards in cavities formed in the bodies of the first cervical vertebra or atlas. Between and behind these condyles is the occipital foramen, through which the spinal cord enters the skull. In quadrupeds, the occipital foramen and its condyles are situated very far backward. It follows (1) That the head is no longer in equilibrium upon the vertebral column but falls forward. (2) That its position has to be raised in order that the animal may see straight before it, the axis of the orbits being altered accordingly. In man, on the contrary, the head is naturally in equilibrium upon the vertebral column. The occipital foramen occupies the middle of the base of the skull. His position with regard to seeing is horizontal; the axis of the orbits is directed forwards and the back of the retina is anatomically arranged in accordance with this."

Dr. Topinard points out that in the European the occipital foramen is situated at an equal distance between the anterior and posterior portion of the entire cranium. In the Negro it is a little more backward; in the anthropoid ape it is considerably so. It recedes in various quadrupeds.

until in the horse it no longer forms part of the base of the skull.

A facial feature which used to be considered as clearly distinguishing man from the monkey, was the presence in man of a chin, that is to say, of a small triangular surface more or less projecting above the inferior border of the jaw. It has, however, been found that the chin is wanting in a certain number of human specimens noted by Quatrefages. Topinard thus sums up an elaborate examination of the various cranial characteristics.

"The head of man is only distinguishable from the head of (other) animals by a single important character—the capacity of the brain-case."

There are three sorts of human crania known, viz., the long (dolicocephalic), the intermediate (mesaticephalic), and the short (brachycephalic). The skulls found in the cave of Engis, near Liège, and at Neanderthal, near Dusseldorf, are dolicocephalic. Sir Charles Lyell describes the Neanderthall skull as the most brutal of all known human skulls, and it is many respects much nearer to the chimpanzee than it is to the European.

Dr. Paul Broca, pointing out the ethnic differences between the Celts and the Belgæ of Julius Cæsar, says: "Whilst the true Celtic skull is brachycephalic, that of the Belgic or Kymric race is dolicocephalic."

We come now to the brain itself. The brain of the human fœtus is at first smooth. The fissures are next seen, then the sulci or furrows, then simple convolutions. As age advances the convolutions increase and become more complex. As the convolutions increase in number and tortuosity, and reduce in individual size, so you have brain power. Large and simple convolutions are found in cases of idiotcy and weak intellect. Small and deep convolutions, with numerous foldings, mark large intellectual capacity. The oustiti, a very low type of monkey, has the brain smooth, and only a trace of the Sylvian fissure. In the sagouins some convolutions are visible, and the number of convolutions increases rapidly in the highest cebians and pithecians. Says Topinard:—

"In anthropoids, suddenly and almost without any transition, they have a similar appearance to those of man. All the principal convolutions are there, the type is the same, the difference

is only in parts of a subordinate character, and in the degree of convolutions, which varies also in man, and is peculiar to him." "Between the smooth brain of the oustitis and the marvellously complicated brain of chimpanzees and ourangs, there is a gap," says Broca, "while there are faint shadows of difference between the latter and that of man. The enormous and complex mass of convolutions in man is composed of the same fundamental folds, united by the same connections and separated by the same sulci. These primary convolutions, these essential parts, common and only common to all human brains, are found without exception in the brains of the ourang and the chimpanzee."

It was for a long time thought that man was distinguished from the monkey by the presence of the mamillary tubercles, little round bodies situate at the base of the brain, and of which the use is not known; but these mamillary tubercles have been discovered in the chimpanzee, the ourang, and the gibbon.

Considerable attention has been paid to the weight of the brain, and the following summary is given in Gray's Anatomy:

"The average weight of the brain in the adult male is 49½ ozs., or a little more than 3 lbs. avoirdupois; that of the female 44 ozs.; the average difference between the two being from 5 to 6 ozs. The prevailing weight of the brain in the male, ranges between 46 ozs. and 53 ozs.; and in the female, between 41 ozs. and 47 ozs. In the male the maximum weight out of 278 cases was 65 ozs., and the minimum weight 34 ozs. The maximum weight of the adult female brain out of 191 cases was 56 ozs., and the minimum weight was 31 ozs. The weight of the brain increases rapidly up to the seventh year, more slowly to between sixteen and twenty, and still more slowly to between thirty and forty, when it reaches its maximum. Beyond this period as age advances and the mental faculties decline the brain slowly diminishes in weight, about an ounce for each subsequent decennial period."

But in taking the weight of the brain regard must be had to stature. The brain amongst some people is heavier in tall persons than in short ones. Allowing for such considerations and for abnormal cases the size of the brain bears a general relation to the intellectual capacity. Cuvier's brain, the heaviest yet weighed, was 64 ozs., the brain of an idiot seldom weighs more than 23 ozs.

Topinard points out that the reason that the brain of a woman is lighter than that of the man is that she has less

cerebral activity to exercise in her sphere of duty. The size of the woman's brain was, he says, formerly larger in the department of Lozère, because the woman and man naturally shared the burden of their daily labor, and, he adds, that the weight of the brain increases with the use we make of that organ, with the exercise of certain professions; in a word with the degree of intelligence.

Dr. A. Weisbach, who has devoted considerable pains to ascertain the brain weights—with reference to stature, age, sex and disease—of Austrian peoples—Magyars, Czechs, Italians and Germans, affirms that so far as these are concerned:—

"Age influences the brain in males and females in an inverse mode, in so far as the total weight is, between twenty and thirty, greatest, and then diminishes with advancing age, which decrease is divided in the separate cerebral sections, in such a manner that the cerebrum in males becomes with advancing age relatively larger and the occipital brain smaller. In females (German) the total brain weight is also, between twenty and thirty, greatest, after which time it steadily diminishes; but with this difference from males, that in the former the cerebrum becomes with advancing age, relatively smaller, the occipital brain (or the cerebellum and the pons alone) becomes relatively larger."

Dr. J. Barnard Davis affirms that "the skull and brain will always remain the purest bases of the classification of the human races," but adds that "unless there are some essential differences in the organisation of the brain which probably may always elude human scrutiny, there is no more certain means of classifying the different races of men than by taking the whole of man's organisation into account with color and form, and especially, primarily and chiefly his cranium, the form and dimensions of his skull."

Anthropoid apes are only found in hot countries. Man is found in every region of the globe, and inures himself to all climates and all conditions of life. This because he is omnivorous, and knows how to clothe himself, and to manufacture weapons and implements.

"The Esquimaux," says Topinard, "subsists on oil and the flesh of seals; the Todas of the Nilgherries on milk and pulse. Some tribes live on fish and shell-fish, and take sea-water as a beverage. Others mix clay with their food, while civilised nations obtain their supplies from all sources. Man cooks his food, but he does not despise the raw mollusc, or undressed fish,

or the raw flesh of the mammalia. Unlike any other animal he rears cattle and devotes himself to agriculture. He makes use of various animals as the dog, the cat, the camel, the reindeer to subserve his own purposes, and even his fellow creatures, be they black or white, are equally under his dominion. In this respect some animals imitate him—as the red ants in their treatment of the black ants."

Many tribes have been found unable to count above a certain number, some not more than two, and a Bosjesman was found who, though intelligent in other respects, was incapable of even adding one and one together. In his family man is monogamous or polygamous, the gorilla and chimpanzee are monogamous, and are said to be very faithful to their partners.

The Todas destroy in the cradle all female children beyond a certain number as being useless. Man, like many other animals, lives in society—

"The Soko," says Topinard, "an anthropoid ape, lives in a troop of ten individuals on the banks of the river Lualaba. Many species of monkeys, like man, select a chief, who directs their operations, and to whom they submit. The howlers or mycetes, belonging to the cebian family, hold meetings, in which one of them speaks for hours at a time in the midst of general silence, succeeded by great excitement, which ceases as soon as the speaker gives the word of command. Other monkeys combine to plan an excursion; divided into detachments, some plunder and tear up roots, others make a chain for the purpose of carrying them from hand to hand; others are placed as sentinels to keep watch."

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LECTURE III.

Many of man's faculties are found more highly developed in some one or other of what are called the lower animals. As Topinard puts it, it is not the exclusive possession of special faculties which marks man's supremacy, but the measure of these generally, and the holding them in comparative equilibrium. The character claimed to be peculiar to man is the faculty of language, or that of uttering articulate sounds. "Man," says Hovelacque, "is man in virtue of the faculty of articulate speech." But ought not every distinct sound which is used to convey a distinct idea be considered articulate? Here, too, it must be noted that, most distinctly, many animals are able to communicate with one another. They have intonations and modulations of voice which express fear, joy, suffering, and hunger. They make themselves understood by those of their own species, and though, as a general rule, they do not articulate, yet there are — at least, in the case of the cebian monkeys and in some birds—sounds or syllables more or less jumbled together to which it would be difficult to deny the word articulate. The operations which result in language are—1. Thought; 2. The desire and volition to express the thought; 3. The faculty of expression first by sounds, which have been termed by Darwin inarticulate, but which may certainly be termed emotional cries, by gestures and muscular movements of the features; 4. The faculty of articulation; these two last including the necessary mechanism of the nerves and muscles—the *modus operandi* of the nerves being here, as in all other cases, yet very imperfectly understood.

The exercise of the faculty of articulate speech is, so far as can be judged, dependent on the "integrity of a very circumscribed portion of the cerebral hemispheres, and more especially of the left. This portion is situated on the upper border of the Sylvian fissure, opposite the island of Reil,

occupying the posterior half or probably not more than the third part of the third frontal convolution." It is by careful examination of those persons subject to aphasia that this localisation has been made clear. By aphasia is here meant, as explained by Broca and by Ferrier, not speechlessness from paralysis of the mechanism of articulation, nor speechlessness from general cerebral disturbance, such as emotional shock, etc., but the inability to express thoughts in articulate speech, because they have lost the ability to remember words; where such aphasia has existed there has almost always been found on examination "a very decided lesion of the posterior half of the right or left third frontal convolution." Nearly always the lesion has been found on the left side.

Taking what, for want of better words, we have described as the faculty of articulate speech as the special characteristic of mankind, we have next the fact that there are to-day linguistic groups in which there is not only no common grammatical point of identity, but in which inflection itself is differently treated. Those who hold this urge with Hovelacque, that "if the different linguistic groups known to us are irreducible they must have taken birth independently and in quite distinct regions. On this it follows that the precursors of man must have acquired the faculty of speech in different localities independently, and have thus given birth to several races of mankind originally distinct."

A large number of languages have perished, all existing languages have been subjected to considerable change. Languages are affected by the struggle for existence, they too illustrate the survival of the fittest. The farther we go back the more numerous do we find the independent linguistic families.

While, at first, difference of race is marked by difference of language, this does not in all cases continue. Not only do languages, like races, die out, but one language absorbs others, and is spoken by races to whom it was not original. So that to-day, and during the historic period, language and race have ceased to be convertible terms. Different races often speak one and the same language, and one and the same race may be found speaking different languages.

The anthropologist is aided by the study of pathology in

trying to fix man's place in the animal kingdom. Diseases to which man is liable are largely common to other animals of the mammalian series. In all you find instances of imperfect development, of diseases acute and transient as well as those chronic in character. All are liable to ailments peculiar to youth and to old age. There are as great differences in the diseases affecting the various types of mankind as there are between the diseases of man and those of other animals. Man may be inoculated with some diseases of other mammalia: they in turn in like manner have been inoculated with human diseases. In skin diseases there is of course a wide difference of degree in the affection of the skin of the European, the Negro, and the horse; and in the lower animals, the nervous system being less impressionable, fever is less marked.

As with man so with the rest of the mammalia you find dyspepsia, asthma, scrofula, and cancer. In all, the increase or diminution of the constituent elements of the blood results in scurvy, dropsy, or anæmia. They have similar diseases in teething. Monstrosities are produced during embryonic or fœtal life and are found in man and other mammalia. Disease of the brain is not limited to man, and here idiotcy has a special interest for the anthropologist, because in cases of idiotcy the faculties have never attained their full development, and idiotcy exhibits the brain of the human being less developed, more or less stunted in growth, and approaching more to that of other animals.

Sometimes in idiotcy the brain is of natural size, but the convolutions are very large and less flexuous or imperfect at some point. Sometimes it is wasted away either wholly or on one side in its frontal, parietal or occipital lobes. In one case the parietal and occipital lobes were so shrunken that the cerebellum was uncovered as in the case of the kangaroo.

There are some curious cases given of what is called microcephalus, that is, where there has been a general or partial arrest or perversion of development in one part of the brain prior to birth. Here, in the absence of complication, the brain continues to grow after birth, but grows irregularly and slowly. In two cases exhibited as Aztecs, a man of thirty-two and a woman of twenty-nine, the intellectual capacity was scarcely that of a child of three years of age,

and their language was limited to about fifteen words uttered in jerks.

Having ranged man as one family, first in the order of primates, the first in the class of mammalia, anthropology seeks to distinguish the various divisions of this human family, and tries to discover whether these divisions are to be arranged as genera or species or varieties. By variety is meant an assemblage of individuals presenting common characteristics and thereby distinguished from groups having other common characteristics. The variety is transient and accidental or permanent. In those who hold the transformist view there is no distinction between permanent variety and species. But those opposed hold that species are immutable—that is, the changes never go beyond certain limits.

Broca says—

"The varieties of mankind have received the name of races, which gives the idea of a more or less direct relationship between individuals of the same variety, but does not decide either affirmatively or negatively, the question of relationship between individuals of different varieties."

The attempts at classification of races have been so numerous that it is impossible in this space to even state fully the principal endeavors. The difficulties of classification have been increased by those who took man back to an universal deluge, and from three men, all the sons of one man, traced three distinct chief or only races by which the world was peopled.

In 1772, F. Bernier classified four races—white in Europe, yellow in Asia, black in Africa, and Laplanders in the north. Linnæus divided the genus man into three—civilised man, savage man, and monster man: the last includes the microcephales; the savage man, dumb, hairy, and walking on all fours; the civilised man he divided into four varieties:—European, with flaxen hair, blue eyes, light skin; Asiatic, with blackish hair, brown eyes and yellowish skin; African, with black woolly hair, black skin, flat nose and thick lips; and American, with tawny skin, long black hair and beardless chin. Blumenbach increased to five human varieties—Caucasian, Mongolian, Ethiopian, American and Malay. Desmoulins raised the number of races to sixteen, besides secondary races. Three classifications need carefully

examining by all students of Anthropology—those of Isidore Geoffroy Saint Hilaire, Professor Huxley and M. de Quatrefages, which are thus stated by M. Topinard :—

"The classifications of Isidore Geoffroy Saint-Hilaire are two in number. In the first place he distributes his eleven principal races according to the character of the hair, the flatness or projecting form of the nose, the color of the skin, the shape of the eyes, and the size of the lower extremities. In the second he admits the following human types: the first, or Caucasian, with the face oval and the jaws vertical (orthognathous); the second, or Mongolian, with the face broad in consequence of the prominence of the cheek-bones (eurygnathous); the third, or Ethiopian, with projecting jaws (prognathous); and the fourth, or Hottentot type, with wide cheek-bones and projecting jaws (eurygnathous and prognathous). This division has not been settled finally, but the bases of it are excellent.

"The classification of Mr. Huxley includes two primary divisions: The Ulotrichi, with woolly hair, and the Leiotrichi, with smooth hair. (1) Ulotrichi. Color varying from yellow-brown to the jettest black; the hair and eyes dark, and with only a few exceptions they are dolichocephales (elongated head). Example: the negroes of Africa and the Papous. (2) Leiotrichi. These are divisible into four groups: the australoid group, with dark skin, hair, and eyes; the hair long and straight, prognathous skull, with well-developed superciliary ridges. Example: the blacks found in Australia and in the Deccan, and perhaps the ancient Egyptians. The mongoloid group: yellowish-brown or reddish-brown skin, dark eyes, long, black and straight hair, mesaticephalic skull. Example: the Mongols, Chinese, Polynesians, Esquimaux and Americans. The xanthochroic group: pale skin, blue eyes, and abundant fair hair, skull mesaticephalic. Example: the Slavonians, Teutons, Scandinavians, and the fair Celtic-speaking people. The melanochroid group: pale-complexioned, dark eyes, hair long and black. Example: Iberians and black Celts and the Berbers.

"There are many objections to this classification. The form of the head, for example, is not always exact. If the Chinese and the Polynesians of the third group are mesaticephalic, the Esquimaux are the most dolichocephalic to be found on the globe, and the Mongols among the most brachycephalic.

"The best classification, apart from the monogenistic principle upon which it is based, is that of M. de Quatrefages. The eminent professor at the Museum of Paris regards the whole of the human races, 'pure or regarded as such,'* as a single stem

* "The monogenistic theory does not recognise the existence of really pure races. All being derived from a single individual, and being

with three trunks—the white, the yellow and the black—which are divided into branches, and these again into boughs, upon which the families divided into groups are grafted. The branches of the white trunk are the Aryan, the Semitic and the Allophyle (Esthonians, Caucasians, Aïnos); those of the yellow trunk are the Mongolian or meridional, and the Ougrian or boreal; and those of the black trunk, the Negrito, the Melanesian, the African and the Saab (Hottentots). As examples of the boughs we may mention the three of the Aryan branch—the Celt, the German and the Slav; the two of the Semitic branch—the Semitic and the Libyan; the two of the Mongolian branch—the Sinican (Chinese, etc.); and the Turanian (Turks). As examples of families: the Chaldean, the Arabic, and the Amhara of the Semitic bough; the first furnishing the Hebrew group, the second the Hymyarite and Arabian groups, and the third the Abyssinian group. M. de Quatrefages admits besides, 'the great races belonging more or less' to one of the three trunks. So among those of the yellow trunk, races 'à éléments juxtaposés' (the Japanese), and the races 'à éléments fondus' (the Malayo-Polynesians). In fact, the majority of classifications go on progressing. We see them commencing timidly, then multiplying their divisions, and then descending to details. Questions as to geographical boundaries are the first to attract attention, then physical characteristics, language, and subsequently records of every kind, both ethnic, historical and archæological."

Classification of races is determined by physical characteristics. 1. Anatomical, which are to be studied in the laboratory; and 2. External, to be observed on the living subject. There is a vast difference in the value of the estimate of these characteristics. The anatomical studies are conducted with care and method, the results are carefully checked and verified. Observations on the living subject are usually by a traveller in a foreign land. Sometimes occupied with other matter the traveller does not note with sufficient exactness. Sometimes his prejudices or preconceived notions influence his observations, and it is always more difficult to verify observations made in a far off land and amongst unfamiliar

gradually produced by the influence of external conditions, the epithet is not absolutely applicable to them at any period of their existence. In the ancient polygenistic doctrine a definite number of races have existed from the first, with characteristics such as we now find them to possess, and consequently have remained pure. In the transformation theory also races are never stationary, or at least are not so as far as our finite vision can make out; their purity therefore is always relative, as in the monogenistic theory."

peoples. For the knowledge of the characteristics of ancient people of whom there are no longer living representatives we are indebted to bones.

Either to judge living races, or those who have died out, craniology is not only first in importance but gives higher results, because cranial differences have been more exactly studied than have the differences of other parts of the skeleton. The observations of Paul Broca are entitled to the first and most important place, and in this country the valuable labors of Dr. C. Carter Blake in relation to craniometry ought not to be passsed without notice. Out of the many cranial differences which it is impossible even to index here we will only take that of cranial capacity. The inferior races have much less capacity than have the superior races. The Australians are the lowest, having, according to Topinard, a mean cranial capacity of 1224 cubic centimetres. The capacity increases in the yellow races, and attains its maximum in the white. The Auvergnians have 1523 cubic centimetres of cranial capacity, the Parisian 1437. The smallest known is a native of the Andaman Islands, with only 1093 cubic centimetres.

In measuring the face, the part lying below the eyebrows is longest in the Esquimaux and Chinese and shortest in the Lapps. The Chinese and Caledonians have the broadest face, the Hottentots the narrowest. Broca urges that the nasal index is one of the best characteristics for determining varieties of the human race. The nasal index is the ratio of the maximum breadth of the anterior nasal orifice to the maximum length of the nose taken from the nasal spine to the naso-frontal suture. That is, in the Hottentot you get the short thick nose, in the European the long thin nose. This was shown in M. Broca's tables, where on a line of 100 a Bosjesman figured, breadth 72, length 22; a Russian, breadth 35, length 71.

The lower jaw furnishes special characteristics, noticeably, in the projection or absence of the chin. In European races the chin is in front of the perpendicular; there is, in the lower races a receding, so that, although the Negro chin is still in front, it is but very slightly so. In the Anthropoid ape the recession is still more marked, the chin is no longer in front; and M. Topinard tells us that examples have been found in some prehistoric skulls which exhibit

all the intermediate gradations between man and the anthropoid ape.

Although the remainder of the skeleton has not yet been studied with the same care as the skull, there are many important race characters already distinctly marked. Amongst these are: the perforation of the humerus met with as a common characteristic in bones of the polished stone period and diminishing in frequency since the commencement of the present era; the sabre-like form of the tibia traced back to the ancient stone, and polished stone periods; the channelled fibula and the *femur à colonne*. The last three are, so far as yet known, characteristics of one race in Western Europe; the perforation of the humerus marking another race. The proportional length of the various parts of the skeleton and the relation of these to the anthropoid ape show in various races, superiority in some points and inferiority in others in the same individuals.

Anthropology has until lately not received great aid from the dissecting-room. The bulk of subjects have been white, and the comparatively few negroes and mongolians dissected were generally not examined with sufficient care nor with the view of detecting and recording differences. Now this is changing, and greater exactitude is being observed. Sœmmering and Jacquart have shown that the nerves of the negro, particularly those at the base of the brain, are larger than those of the European. The cerebral substance in the Negro is not so white as in the European. The convolutions of the brain are large and less complex in the inferior races.

The length of the arm serves to help to mark race. In the Negro the arm is longer than in the European, in one case, at least, being scarcely distinguishable in proportional length from the gorilla.

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LECTURE IV.

THE color of the skin, hair and eyes is the result of the production and distribution of coloring matter. The skin of the Scandinavian is white, almost without color, or rather appearing rosy and florid, owing to the transparency of the epidermis, allowing the red coloring matter of the blood to be seen. The skin of the negro of Guinea, and especially of Yoloff, the darkest of all, is, on the contrary, jet black, in consequence of the presence in the minute cellules on the deep surface of the epidermis, of black granules, known by the name of pigment. This pigment is found in all mankind, whether black, yellow or white, the various tones of color being consequent on the quantity. There is a red coloring matter in the blood, a black coloring matter of the skin, and a yellow coloring matter secreted in the liver—whence the color of the tissues in jaundice. "There are thus," says Topinard, "three fundamental elements of color in the human organism—namely, the red, the yellow and the black, which mixed in variable quantities with the white of the tissues, give rise to those numerous shades seen in the human family."

From the mixture of these fundamental colors and from the influence of external conditions issue all the known shades. Amongst the whites there is a great variety, the rosy Scandinavian differing considerably from the florid English and Dane. The yellow tint of Eastern Asiatics is still more varied, being sometimes almost indistinguishable from white, sometimes olive green, and passing through every stage from pale yellow to brown or gingerbread color. Amongst American Indians there are all shades of color, from the light tint of the Antisians of the Central Andes to the dark olive of the Peruvians and the negro black of the ancient Californians. In Polynesia, copper color is common with very light yellow and brown tints. In Africa, red and

yellow are very common. The Foulbas are of a rhubarb yellow, those of pure blood approaching red. In many parts of Africa the negroes insensibly blend with the yellow and red. The Hottentots, and especially the Bosjesmans, are of a yellow gray.

The color of the skin is associated, if the race be pure, with a certain color of eye and hair. "Thus," says Topinard, "those with white skins of a rosy hue, which cannot bear the sun, have usually light eyes and hair. Those with white skins, which readily tan with the sun, and those with yellow, red or black skins, have, on the contrary, dark hair." The color of the eye, or rather of the two circles of the iris, is easily mistaken, the external circle being darker than the internal and the intermediate zone being lighter than either. Dark blue and light blue eyes usually belong to fair people, and, associated with fine silky and yellowish or flaxen hair, are more characteristic of a race group than any other shade. When associated with black hair, they are a sign of mixed breed. Grey, greenish and neutral tinted eyes are characteristic of the Celtic race.

Hair consists of root, including bulb, and stem. In the centre of the stem is a sort of canal, transparent in Europeans with light hair; more or less opaque, but still visible, in Europeans with black hair, Mongols and Americans; and invisible in Negroes, Papuans and Malays. The size of the stem is the cause of the harshness and rigidity or fineness and flexibility of the hair. The thinnest and the flattest hair is that of the Bosjesmans, Papuans and Negroes; the most cylindrical is that of the Polynesians, Malays, Siamese, Japanese and Americans; Europeans are between the two. Topinard says that the hair

"Presents definite anatomical characters which alone might be taken as a basis of classification for the races of mankind. Three groups might thus be portrayed: (1) Flat or woolly hair, characteristic of Negroes; (2) Large and coarse cylindrical hair, belonging to Mongols, Chinese, Malays and Americans; (3) Hair intermediate in shape and size peculiar to European races. The first group might be divided into two, according as the hairs are inserted in tufts as in Papuans and Bosjesmans, or in a continuous layer, as in other Negroes. The third might be classified according, as the hair is brown as in our Southern races, or light as in the Northern. Lastly, by comparing the character of the straight hair with the pure black color of the skin in

certain races, we might have a further group comprising the Australians, Hymiarites, etc. Thus we should have six fundamental divisions bearing upon one and the same organ."

Examining the features in profile there is the oblique or prognathous countenance in which the two jaws project and the lips are large and upturned. This is the negro type. The other, sensibly vertical or orthognathous, in which the lips are fine, straight and small. This is the European type of face, which, looked at in front, is developed and projecting in front of the median line, the sides receding and becoming narrower. In the Mongolian type, the middle portion of the countenance is flat and the sides become wide and project out. A straight contracted forehead is a feature of inferiority; a broad ample forehead a mark of superiority. Microcephales and idiots have the receding forehead. In the Esquimaux and the Chinese what is called the "almond eye" is a strong race character. "The internal part of the eye is lowered whilst the external has an upward direction. The internal angle is covered by a fold of loose integument. This fold is slightly stretched over the angles of the eyelids and covers the caruncula lachrymalis which is visible in the European, and forms as it were a third eyelid, in the form of a crescent." The nose is wide and flat in Mongols and negroes; in Bosjesmans and the lowest type of negroes the sides of the nostrils are elevated somewhat upwards and outwards, exposing the internal surface and approximating in this to the Simian types. Delicacy of shape of the lips and smallness of the mouth are European features. In Kabyles the ears project out; in Europeans they are oval and well defined; in negroes they are round or approaching to square. There is a noticeable cutaneous odor in various races, but its diversity has hardly yet been noted with sufficient exactness. Having given a variety of points as to the external differences of the Bosjesman and the European, Topinard declares that the line of separation as regards these in a morphological point of view is as much "as between each of the anthropoid apes, or between the dog and the wolf, the goat and the sheep."

There are, Topinard thinks, reasons for believing that the mean normal longevity is not the same in all races. Decrepitude shews sooner in some races. The Australians and Bosjesmans are old men at a period when the European is in

full enjoyment of his faculties, both physical and intellectual. In the negro races woman fades away much more quickly than in the white, and the bodily development of the negro is generally in advance of that of the white man.

Atavism is the tendency to revert to features common to previous ancestors; thus a human being may have no likeness to his father or mother, but may be the reproduction of his great grandfather or great grandmother. There are numerous cases of reversion to ancestral forms of extreme remoteness. There is the double and apparently hostile tendency in each individual, or generation of individuals, to divergence or variability of character, and to concentration or perpetuation of these characters. Crossing and inheritance require full study by anthropologists. Crossing is the union of two individuals belonging to differing varieties or races. Inheritance the ability of living beings to repeat or reproduce themselves with similar forms and attributes. Inheritance results in the permanence of types such as we find represented on Egyptian monuments of 5,000 to 6,000 years' antiquity identical with the Fellah who to-day gains his livelihood on the banks of the Nile. It is yet to be settled how far the crossing between races anthropologically remote affects the progeny as to superiority and fecundity, and though it is strongly urged that as races increase in superiority fecundity diminishes, a careful observation and examination is needed of all facts bearing on the question.

Varieties of race are produced prior to birth by influences yet little understood; and in the course of life by surroundings, what M. de Quatrefages calls *milieux*, that is "the *ensemble* of conditions or influences of every kind which may act upon organised beings;" or with Topinard, "all the external causes capable of producing, either directly or indirectly, a change in living organs." Nutrition is here of prime importance. If, in consequence of insufficient nutrition, the ossification of the skeleton is not regular, the individual will be short in stature. If this be repeated through many generations it will become habit, and then a regularly transmissible character.

The more the brain works the more it continues to increase beyond its ordinary growth. So says Topinard: "The small size at the present day of the skull of women

relatively to that of men, as compared with that which it was at the prehistoric period represented by the two beautiful series from the cavern of L'Homme Mort and the Baye caves in the department of La Marne, would arise from an opposite cause."

Climate is a most important element as affecting race. One race evinces a capability of living in some latitudes rather than in others. The English, who become habituated to the climate of the United States, St. Helena, and the Cape of Good Hope, fail to become so habituated in the Antilles and in India. The Germanic races thrive in the United States, but die out in the Tropics. The Dutch live under the most favorable conditions in the Cape, but perish under the scorching climate of the Malay peninsula. In Madagascar and in Senegal no European race can hold out. The brown races show great power of acclimatisation. In cold regions Europeans do not readily become acclimatised, and the fair population of Iceland is now decreasing, and this is supposed to be in consequence of the island becoming gradually colder. M. Bertillon divides the results on the individual and his progeny of sudden transplantation to a new climate into "(1) sudden diseases; (2) chronic consecutive anæmias which place the individual in an unfavorable condition to resist accidental diseases, or make him quickly look old; (3) diseases of early infancy in offspring born in the country; (4) physical and intellectual degeneration and the infertility of the second and third generations."

Acclimatisation is more successful if gradual, that is by small stages of climatic difference, as has been the case with the great migrations. Permanent acclimatisation is rendered more easy by slight crossing with native races, or with settled races with greater power of acclimatisation. Thus a small shade of negro blood lessens the tendency of the European to contract yellow fever.

Besides anatomical and physiological race characteristics, of which some instances have been given, the anthropologist enquires into man's customs, his language, his migrations, the relics of his earliest industry—in a word, into all those things which result from the association of men with each other.

There are two characteristics common to the whole human

race, one of which is also common to the ape: imitation and improvement. The ape repeats what it sees done. Man repeats and profits by what he sees, and is more or less capable of improving upon what he so sees. But the ability of man to appropriate and utilise all that may be rendered subservient to his wants and desires, and to transform himself intellectually, is not equal in all races. Certain intellectual differences are found persisting amongst certain peoples, probably each difference corresponding to certain cerebral differences. Here we are brought specially face to face with the differences of language.

Of the about 800 known languages, living and dead, there are three types: (1), the monosyllabic, as the Chinese and its dialects; (2), polysyllabic or agglutinative, as the idioms of the American, Basque, Berber, Mongolian, etc.; (3), the inflexional, as the Semitic and Aryan languages, the last including most of the European. Some of these languages "are so perfectly distinct in their mechanism and in their constituent elements—as the Indo-European or Aryan, and the Syro-Arabic or Semitic, in spite of all the attempts of specialists to find in them points of contact—that they give one the idea that at the time of their formation the races which spoke them lived absolutely separated, without any communication with any other races." If it be assumed that the type of language is the inevitable product of the cerebral organisation, it will be seen that very early types of language may be of great aid in helping to discriminate between races, although not conclusive alone in marking race.

If all the existing varieties of human kind were pure, then classification would be easy; it would be enough to sum up their respective differences and resemblances, but this is not possible. As Topinard puts it:

"Races have been divided, dispersed, intermixed, crossing in various proportions and in all directions for thousands of ages. The greater part of them have relinquished their language for that of their conquerors, or for a third, or even for a fourth; the principal masses have disappeared, and we find ourselves no longer in the presence of races, but of peoples, the origins of which we have to trace, or to make a direct classification of. In other words, there are two orders of classification which we must not confound, namely, the classification of the masses of human

beings such as the flux and reflux of time have left us, and the classification of races such as we are able to arrive at after a minute process of analysis. The former is ethnological, the latter anthropological."

It is in the past that the anthropologist tries to trace the histories of the various races in order that he may comprehend how the present races have grown. Real history goes back only a few thousand years, when it is imperfectly and sometimes incoherently supplemented by tradition and legend. When these cease to be useful aids, the anthropologist especially devotes himself to archæology, and more particularly to prehistoric archæology for further guidance. Under archæology is included the metal age, while the prehistoric division comprises the ancient and polished stone epochs. The lake dwellings, the dolmens, the caves, the barrows, the kitchen middens in Europe, Africa and America, each and all help us with clue to trace man in the far-off yesterday of human kind.

The metal age goes back until history fails, and tradition and legend so die out, that it is not possible accurately to do more than fix a minimum of time, and to leave the "how much more ancient yet?" an unsolved problem. The neolithic or polished stone period stretches out still more immeasurably into the past, and the rough stone or palæolithic period is so much more vast in duration that the previous twain seem brief indeed when measured beside it. Great glacial periods, age of cave bear, of mammoth and of reindeer—all these serve as time-marks to roughly note the centuries of chiliads, as we grope in the mighty yesterday in our search for traces of prehistoric man.

Without attempting here the announcement of any personal theory on the origin of man, I conclude with Topinard's *résumé* of the possible genealogy of man according to Hæckel.

"At the commencement of what geologists call the *Laurentian* period of the earth, and of the fortuitous union of certain elements of carbon, oxygen, hydrogen, and nitrogen, under conditions which probably took place only at that epoch, the first albuminoid clots were formed. From them, and by spontaneous generation, the first cellules or *cleavage-masses* took their origin. These cellules were then subdivided and multiplied, and arranged themselves in the form of organs, and after a series of transformations, fixed by M. Hæckel at *nine* in number, gave origin to

certain vertebrata of the genus *Amphioxus lanceolatus*. The division into sexes was marked out, the spinal marrow and *chorda dorsalis* became visible. At the *tenth* stage, the brain and the skull made their appearance, as in the lamprey; at the *eleventh*, the limbs and jaws were developed, as in the dogfish: the earth was then only at the Silurian period. At the *sixteenth*, the adaptation to terrestrial life ceased. At the *seventeenth*, which corresponds to the Jurassic phase of the history of the globe, the genealogy of Man is raised to the kangaroo among the Marsupials. At the *eighteenth*, he becomes a Lemurian: the Tertiary epoch commences. At the *nineteenth*, he becomes Catarrhinian, that is to say, an ape with a tail, a Pithecian. At the *twentieth*, he becomes an Anthropoid, continuing so throughout the whole of the Miocene period. At the *twenty-first*, he is a man-ape, he does not yet possess language, nor, in consequence, the corresponding brain. Lastly, at the *twenty-second*, Man comes forth, as we now see him, at least in his inferior forms. Here enumeration stops. M. Hæckel forgets the *twenty-third* stage, that in which the Lamarcks and Newtons made their appearance. Although having attained so lofty an eminence, Man must have had a very low origin, in no way differing from that of the first and most simple organic corpuscles. What he is now in the womb, he would have been permanently on making his appearance in the animal series."

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